DEVELOPMENT OF A SOLID FEED BLOCK FORMING MACHINE FOR CATTLE

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(138123V)

Thesis submitted in partial fulfillment of the requirements for the degree Master of Engineering in Manufacturing Systems Engineering

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DECLARATION

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Dr. H.K.G.Punchihewa

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Abstract

Livestock statistics show that there are 1.2 million milking cows and 0.4 million buffaloes in Sri Lanka and the Department of Census and Statistics shows an annual per capita consumption of milk and milk products of about 4.6 kg/year. However, these values are comparatively low compared to the developed countries. Therefore, achievement of the self-sufficiency levels in dairy industry of Sri Lanka needs significantly both in growth and productivity. The issues which are slowing down or hampering the growth and productivity can be categorized on milk production related, distribution and marketing related, extension and support service related, consumer concern related, policy related and feeding related. Although, the nutrition is a key factor for the performance, health and welfare of dairy cattle, the prevailing cattle feeding has become an issue today for growth and production became of mostly primitive nature of practice, which is a challenge for the increased commercialization of dairy industry. Consequently, it has been identified that the well-recognized method of feeding cattle in commercial dairy industry is solid nutritious feeding blocks which are made of hygienically prepared agricultural residues.

Aim of this research were producing suitable feed block and developing block making machine for the cattle in Sri Lanka. The objectives of this research were to identifying the requirements for cattle feed blocks and their manufacturing, to examine suitable shapes and sizes for feed blocks, and to design and manufacture a feed block machine and to test the machine for verifying the results.

Suitable block forming methods, technologies and the suitable machineries were recognized through literature survey, brainstorming sessions and experimental procedures. Accordingly, design and fabrication of a novel block making machine was successfully completed. Suitable size and weight of the block, recommended recipes, production capacity of the machine, block forming method and type of power source were identified. Finally a machine was fabricated to suit the parameters identified above and was tested. Results revealed that the fabricated machine can address the design requirements of the machine. The production capacity of the machine was 100 blocks/ h with 200 mm × 200 mm ×110 mm size and 2 kg weight.

The solid cattle feed blocks can be used to fulfill the nutritional requirements of dairy cattle under safe conditions with affordable cost. Further, adoption of this technology supports to make an easy feeding mechanism and enhance milk production through available agricultural residues and available technology in Sri Lanka. Adding automatic raw material preparation system and the automatic feeding system to the compaction machine are proposed as further improvements.

Keywords: Agriculture, dairy development, cattle feed, feed blocks, feed block machine

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TABLE OF CONTENTS

List of Figures

List of Tables

1 INTRODUCTION

This chapter discusses the background of this project, its aim and objectives, and methodology with brief overview of each chapter.

1.1. Background

Dairy cattle are bred large quantities of milk for making dairy products and it contributes both national and household economies. This milk contains essential nutrients such as about 75% of dietary Calcium and other nutrients like energy, protein, vitamins, and other minerals [1]. According to the livestock statistics in year 2012 indicates that 1.2 million milking cows and 0.4 million buffaloes were available in Sri Lanka. Approximately 70 - 75 percent of total cattle and buffalo population is in Dry zone where the both rain fed and irrigated farming systems available [2].

According to the report in Department of Census and Statistics in year 2012 Sri Lanka is not self-sufficient in dairy sector. Annual per capita consumption of milk and milk products is about 4.6 kg/year which is comparatively low compared to the developed countries. Local dairy production is nearly 33% of the requirement of current consumption rate and total national milk production was 237.6 million liters [3]. The balance amount is supplied by the import parity which cost around 27 billion rupees annually.

Total milk production of a lactating cow mainly depends on several factors. Consider about the basic requirements of dairy cow for maximum production, these include good feed and clean water, good health, comfortable environment, e.g. temperature, clean floor and freedom from fear and distress to exploit the cow's full genetic potential and also there is need to have a good nutrition program and meet all other needs [4].

Nutrition is a key factor in the performance, health and welfare of dairy cattle. The nutrient requirements for dairy animals for their growth, maintenance and milk production vary with their body weight, age, body conditions and total production. Dairy cattle require at least 17 minerals and three vitamins in their diet for optimal milk production, reproductive performance, and herd health. The major minerals (macro minerals) required are calcium, phosphorus, magnesium, potassium, sodium, chlorine, and sulfur and the much smaller minerals required are (micro minerals) include iodine, iron, cobalt, copper, manganese, zinc, and selenium [5].

One of the major constraints faced by the dairy farmers in the dry zone and commercial farms in up country is the severe drop in body condition during prolonged droughts due to scarcity of feed [6].Therefore, forage diets need to be supplemented with an additional energy or protein source (concentrates) and minerals to satisfy the cows' nutritional requirements [7].In order to ensure a steady supply of quality feeds for livestock even during the dry season, excess forages could be preserved as silage, hay and feed blocks. These blocks can be improved nutritionally by mixing dry forages or legumes with other feed ingredients such as coconut poonac, rice bran and shell grids etc. They can also be used as an effective feed for livestock, especially for dairy cows during the drought period [8].

From the technical and scientific points of view, the block technology works reliably in improving livestock productivity. Cattle feed block means a solid block which made with handy manner including all the nutritious compounds at required level of animal. Major key ingredients are supplied by agro waste. Considering the abundant, cheap and locally available ingredients for the production of blocks, the beneficial effects on improving the productivity of animals and the growing demand for the supplement, there is a potential that the technology will attain its sustainability. Use of feed blocks rather than forage feeding, it may positively affect to the both animal and the farmer. In animal's side, it's fulfilling daily nutritional requirement, palatable and less possibilities in digestive disorders like bloat, acidosis, etc. In farmer's side, feed block is a compact one due to that it can handle, store and transport easily, can use for feeding during forage scarcity conditions. Animals can be reared with minimal space under intensive conditions with feed blocks.

The task of developing a nutritious cattle feed block using agro wastes and related machineries, has been conducted by National Engineering Research and Development Center for the purpose of uplifting the local milk productivity in Sri Lanka. It has been identified that the well accepted method of feeding cattle in commercial dairy industry whole over the world is the supply of solid nutritious block made out of hygienically prepared agro waste. The surplus of agro waste (mainly hay) after the harvest season could be made available during the dry season. Since, storing hay without further processing is problematic due to its huskiness and the insect attack presence of moisture, apart from the high handling and transport cost. It could be baled or compressed, packed and stored in the farms with minimum storage space for dry season use. In order to solve this problem compression or densification is proposed to be used as a solution. Hay requires suitable binder for densification process molasses is proposed to be used as the binder. In order to improve the nutrient value some urea is able added to this. Suitable dried hay is mixed with the binder mix and densified and tested for shelf life and quality.

This project was initiated based on the research work of making of cattle feed block using sugar cane tops mixing with molasses and other ingredients carried out at the Dept. of Agriculture Engineering & Post Harvest Technology (AE&PHT). Hay blocks made as per different recipes were tested at NLDB and found to be a viable project especially in sugar industry base communities. Therefore the project was stared for developing the machineries required for the production of Hay blocks by NERDC in collaboration with the Pelwatte Dairy products (pvt) Ltd. A semi-Automatic Hydraulic press and an electrically operated mixer were developed at AE& PHT Dept. of NERDC as per the request of Pelwatte Dairy products (pvt) Limited.

Average result of above solid block nutrient content, cost of production, shelf life of the product and animal performances were considered for evaluation. Proximate analysis was done assessing the existing nutrients in feed blocks. The average nutrient content of feed blocks could be expressed as Crude Protein-12.33%, Total Digestible Nutrients-3000k cal /kg, Crude Fat-5.46%, Crude fiber- 20%, Calcium-1%, Phosphorus- 0.4%. Cost per 1 kilogram of feed block is about 45 rupees. It is 80% profitable compare to the commercial cattle feeds available in the market. Shelf life of the designed product is about 3 months subjected to the storage conditions provided with sealed polythene package.

This exercise suggested that solid cattle feed blocks can be used for fulfilling the nutritional requirement of dairy cattle under safe conditions with affordable cost. So that semi-automated block foaming machine has been developed to cater the requirements of dairy farmers. Further, such practices would enhance dairy farmer’s access to higher milk production and adopt this technology with available agricultural waste materials and available technology in Sri Lanka.

1.2. Aim & Objectives

The aim of this research was to produce suitable feed blocks for the cattle in Sri Lanka.

Objectives:

1. To identify the requirements for cattle feed blocks and their manufacturing.
2. To examine suitable shapes & sizes for feed blocks.
3. To design and manufacture a feed block machine.
4. To test the machine.

1.3. Methodology

- Detailed literature survey to found out suitable block forming methods, technologies and the suitable machineries.
- Conducted a brainstorming session to find out user requirements.
- Therefore, selected most suitable and reliable block type, forming method and its forming parameters. For using a small prototype system to found most suitable block forming parameters while varying block shapes (Square and cylindrical) and the moisture content of the raw materials.
- Designed feed block forming machine from using above design parameters. This included the design of mechanical and the electrical controlling systems.
- Fabricated the machine using above design.
- After the several tests, analysed its outputs and modified if needed.
- Conducted field tests and hence proved the design details (production capacity, block size, parameters for forming blocks etc.)

1.4. Chapter overview

The project report has seven chapters. A brief description of each section is given below.

Chapter 1: This includes the introduction with the research gap, aims, objective and methodology.

Chapter 2: This includes the literature survey related to the cattle feed. Introduction which discusses the livestock industry, agro climatic zones, dairy farming systems, available feed resources, Feeding strategies in Sri lanka. Nutritional requirement of dairy cows, Issues find for cattle feed, Agricultural by products used in feed block technology, preparation of the feed blocks are the other subtopics. The objective of this chapter is to identify the requirements for different type of cattle feed and their manufacturing processes suit to the Sri lankan context.

Chapter 3: This includes the methodology regarding cattle feed block preparation and making machinery. It is finding the selection of block type which suit to Srilankan context using brainstorming session, selecting a suitable ration form literature and small experimental analysis, finding a block forming parameters by using experiment and hence finding the block forming parameters. Finally design of the industrial machine for making solid feed blocks.

Chapter 4: This chapter includes the design and fabrication of the solid feed block making machine. Hence prove that the parameters found from the above chapters (Chapter 2 and 3) and the results of the fabricated machine. Design includes the design of hydraulic system, design of an electrical control system, design of structural elements etc. And also includes the field testing details once the machine is fabricated. Finally compare the design details and the field testing details.

Chapter 5: This chapter includes the overall discussion regarding the above findings (From chapter 2, 3 and 4) and discusses the variation between design and actual data.

Chapter 6: This chapter includes the overall conclusion of the thesis with the recommendations for future works.

Chapter 7: This includes the overall references which used to fulfill the research gap of this project.

2 LITERATURE REVIEW

This chapter discusses the overall literature review pertaining to the cattle feed. It includes the introduction which discusses the livestock industry, agro climatic zones, dairy farming systems, available feed resources, Feeding strategies in Sri Lanka. Nutritional requirement of dairy cows, Issues find for cattle feed, Agricultural by products used in feed block technology, preparation of the feed blocks are the other subtopics. The objective of this chapter is to identify the requirements for different type of cattle feed and their manufacturing processes suit to the Sri Lankan context.

2.1. Introduction

2.1.1. Livestock Industry in Sri Lanka

Agricultural sector contributes around 13% to the national Gross Domestic Product (GDP). It provides employments to about 33% of the labor force, surpassing the contribution of any other major sectors. The land area under agriculture in Sri Lanka is around 2million ha, which is 30% of the country's total area of 65 610 sq. km. Almost 75% of the agricultural land is under smallholdings, and the number of such holdings is estimated at 1.8 million, with over 90% of them having less than 2 ha. Almost one third of these smallholdings have a mixture of crops and livestock. The livestock sub-sector contributes around 6% to the agricultural GDP and around 1.2% to the national GDP. The area of farm holdings with livestock is around 0.56 million ha, of which 99% are categorized as smallholdings [3].

The role of livestock in agriculture in Sri Lanka is complex and significantly different from that of industrialized nations. The total number of farmers involved in livestock production is estimated at 700 000 and between 30-60% of gross farm income is generated from livestock activities [9].Although the livestock sub-sector has contributed only around 1.2% to the national GDP, primarily, they provide a crucial source of high quality protein by producing milk, meat and eggs [3].

In addition, cattle and buffalo are a primary source of renewable and low cost draught power for a variety of agricultural operations and transport. Other subsidiary products include hides, skins and manure. Livestock also serve as a 'living bank' for many small farmers, cushioning the risks associated with crop production and providing a financial reserve during periods of economic hardship [10].

2.1.2. Agro-climatic zones in Sri Lanka

Sri Lanka has a heterogeneous agro-ecological environment and many workers have made efforts to classify this situation. A particular agro-ecological region represents fairly even agro-climate, soils and terrain conditions and would support a particular farming system with a certain range of crops and farming practices, including forage cultivation and livestock farming [10].On rainfall distribution, Sri Lanka has traditionally been classified into three climatic zones; Wet Zone, Dry Zone and Intermediate Zone. Wet Zone covers the south-western region including the central hill country and receives relatively high mean annual rainfall over 2500 mm without pronounced dry periods. Dry Zone covers predominantly the northern and eastern part of the country, being separated from Wet Zone and Intermediate Zone. Dry zone receives a mean annual rainfall of less than 1750 mm with a distinct dry season from May to September. Intermediate Zone receives a mean annual rainfall between 1750 to 2500 mm with a short and less prominent dry season. In differentiating these three major climatic zones; land use, forestry, rainfall and soils are widely used and as a result, they were divided into 24 agro-ecological regions. Environmental change, availability of more spatial and temporal data has led to the sub-division of the 24 agro-ecological regions of Sri Lanka into 46 sub-regions.

2.1.3. Dairy farming systems in Sri Lanka and available feed resources

Under dairy farming system, country is divided into four agro-ecological regions. Up-Country and Mid-Country, Coconut Triangle, Low Country Wet Zone (Wet Low land) and Dry Zone (Dry Low land) (Table 2.1) are the zones which reflect the effects of both altitude and precipitation [11].

The largest number of cattle is found in the Dry Zone, where herd sizes are also the largest. Relative distribution of cross bred dairy cattle is highest in the mid- and up-country as well in the wet lowlands near Colombo. In the first case, this can be attributed to the temperate climatic conducive to the health and performance of improved animals. While in the second case, it may be attributed to the high milk prices available through the informal market close to the urban area, under which circumstances the risks to improved animals of lowland conditions are acceptable [12].

Table 2.1 : Cattle and Buffalo Systems: Topography, Climate and Animal Husbandry

Zone	Elevation (m)	Rainfall (mm)	Temp. range ^{0}C	Animal types	Husbandry practices
Up country	>450	>2 000	10–32	Pure exotic and crosses; some zebu crosses	Zero grazing, small herds; some tethering
Coconut triangle	<450	1500–2500	21–38	Crosses of exotic breeds. Zebu types, Indigenous animals and crosses, Buffaloes	Limited grazing, tethered under coconut palms medium size herds
Wet lowlands	<450	1875–2500	24–35	As above	Limited grazing, medium size herds
Dry lowlands	<450	100–1750	21–38	Indigenous cattle, zebu cattle and their crosses, Buffaloes	Free grazing, large nomadic herds, Sedentary small herds in irrigated schemes.

(Source: Reference [13]**)**

- ***Up-country***

Up-country or hill country zone lies above 1200 meters average mean sea level and is characterized by tea plantations and dairy production from cattle kept in to estate and village based systems. In the estate-based system, many of the employees in the tea estates rear dairy cattle, generally the European breeds such as Ayrshire, Friesian, Jersey, and their crosses. Average milk yields are reported up to 8 L/cow/day or about 2500 L/cow/lactation. In this estate-based system, the dairy farmers own no land and are dependent upon weeds from the estate lands and fodder gathered from near water ways and other communal and public areas. Manure is often sold. In the village-based system, the majority of smallholders are crop-livestock farmers, growing vegetables and paddy. Manure is a major product from their cattle, with milk often a secondary source of income [12].

- ***Mid Country***

In the Mid-country, European dairy breed crosses are an increasing proportion of the smallholder cattle herds, but there are many crosses with Indian breeds and milk yields are correspondingly lower. They are reported to be about 6 L/cow/day or around 1500 L/cow/lactation. Farms combine a homestead tree garden system with rice production in the low lying land, generally cultivated by buffalo. Land sizes are small encouraging the adoption of zero grazing, with generally two cows and their progenies(Table 2.1).There is an increasing dependence on fodder from off-farm and on concentrate purchases, which are influenced by the level of household income.

- ***Coconut Triangle and Wet Low Lands***

In the coconut triangle and the wet low lands cattle and buffalo form an integral part of the farming systems, helping in weed control and providing manure for the coconut lands. Buffaloes are used principally for draft purposes in paddy cultivation and are kept in almost all the rice growing areas. Some farmers rear dairy buffaloes, pure Indian breeds or their crosses managed under an intensive or semi intensive system. The buffalo milk is generally converted to curd for which there is high demand locally. In both zones cattle and buffalo graze on the fallow paddy fields, as well as on the natural pastures under the coconut plantations and in non-cultivated areas, including common properties [12].

- ***Dry Zone***

In the Dry lowland zone cattle are predominantly indigenous Zebu, although Sahiwal crossbred cattle, and improved buffalo in the eastern Dry Zone, are becoming more common, especially in the Mahaweli irrigated areas. These cattle and buffalo form an important capital asset (an inflation-proof insurance fund) for the peasant farmers, and where there is the possibility to sell milk, it is becoming an important source of income. Many herds are grazed on common lands and in the farmer's or neighbors' fallow paddy fields, and brought to the homestead at night to avoid theft and damage to crops. Feeding of rice straw is common and generally concentrates are not fed. Average herd size is 10 - 25 with some of more than 100 animals. The average production of milk extracted for human consumption from the indigenous breeds is about 1 L/cow/day, with 2-3 times more from Sahiwal [12].

2.1.4. Feeding strategies in Sri Lankan dairy industries

Since ruminant livestock production in Sri Lanka is mostly in the hands of smallholder, major constrains in Sri Lankan dairy industry are seasonal shortages of green fodder and high cost of concentrates. For the resource poor farmers who are dispersed primarily in rural areas, the feeds that are likely to be available are the natural grazing from waste land, cut and carry indigenous grass species from road sides, water ways, paddy fields and bunds, crop residues, and agricultural by-products from industry. Due to the highly seasonal rainfall in many parts of the country, the quality and quantity of available forage also fluctuates affecting the milk yield and lactation length of both cattle and buffalo [10].

While in times of abundance animals are fed on good quality forage with little or no concentrate feed, in times of short supply they are fed on poor quality crop residues like cereal straws and agro-industrial by-products and high amounts of concentrate feed. Feeding strategies need to be developed for an annual cycle and not for separate wet and dry season feeding, highlighting the need for conservation of forages and other feed resources [11].

The feed resources that can be used in addition to natural grasses include fibrous crop residues such as rice straw and maize stover, and agro-industrial by-products such as molasses, rice bran, waste from fruit canneries and brewer's grain. Feedstuffs that result from industrial processing of agricultural products are generally less fibrous in comparison to crop residues, being rich in protein and minerals and containing more fermentable energy. Their source of origin can be from field and plantation crops, tree crops, fruit processing industries and other miscellaneous sources. Some non-conventional feeds like leaves and fruits from multi-purpose trees, shrubs and woody perennial plants and sugarcane tops, contain medium to high levels of protein and are considered as useful additives to low quality diets. Therefore, simple and low-cost technologies in nutrition and management need to be introduced to the smallholder farmers. However, traditional farmers who have reared cattle and buffaloes with minimal inputs do not readily accept innovations, especially when they call for extra time, money and labor. Therefore, innovative approaches that demonstrate clear economic benefits are needed to convince farmers to accept newer technologies [14].

2.2. Nutritional requirement of dairy cows

2.2.1. Energy

To determine the energy requirement (Table 2.2) of dairy animals it has been customary to partition the requirements into that the required for maintenance, on the one hand, and that for production, on the other. Thus factors associated with differences in the body-weight, breed and sex can be considered under the former while the quantity, quality and nature of deposited materials can considered under the later. Since both the maintenance requirement and the extent of production influence the animal's thermal losses, it is necessary that these losses be considered in the calculation of the requirements and the results expressed in terms of metabolizable energy (ME). The ME system was developed in the U.K. by Blaxter and adopted by the ARC in 1965. In the USA, feed rationing for ruminants is also based on energy but the standards are expressed as Net Energy (NE) [3].In Asian countries the use of TDN has been well practiced since these values are available for a wider range of feed. Measurement of Feeding strategy for improving dairy cattle 75 ME and NE is more difficult [15] but it can be predicted form TDN (1 Kg TDN = 4.409 Mcal DE), ME = 08* DE. Net energy for lactation (LEL) (Mcal/lb DM) = (TDN% of DM*of 0.1114) – 0.054 [15].Energy requirements of dairy animals by different systems are shown in table 2.2.The energy requirement proposed by reference [16], [17] and [15]are comparable with each other with a difference of 8-10%. The requirement suggested by Reference [15] is little bit higher than NRC which indicates the higher energy requirement of Zebu cattle.

Table 2.2 : Energy requirement of dairy cows with weight gain of 500g

Live weight (kg)	NRC (1989) [16]		ARC (1980) [17]		Ranjhan (1990) [15]	
	ME (Mcal)	TDN (kg)	ME (Mcal)	TDN (kg)	ME (Mcal)	TDN (kg)
100	6.54	1.72	6.9	1.9	6.6	1.9
150	8.55	2.25	-	2.6	9.4	2.6
200	8.55	2.25	10.7	3.0	10.8	3.0
250	12.31	3.27	-	-	-	-
300	14.15	3.77	14.0	4.0	14.4	4.0
350	16.01	4.29	-	-	-	-
400	17.91	4.82	17.0	5.0	18.1	5.0
500	21.93	5.98	20.0	-	22.1	6.0
600	26.50	7.29	22.4	-	-	-

(Source: reference [16], [17] and [15]**)**

2.2.2. Protein

The protein represents a very important group of nutrients in the feed which are used for a variety of purposes within the body. Their most important function is the supply of amino acids for the production of body protein and for the synthesis of non-essential amino acids. Thus the efficiency with which dietary protein is utilized will depend upon its amino acid composition. For efficient utilization, the feed must supply the correct quality of the essential amino acids and sufficient of the non-essential amino acids to meet the metabolic demands of the dairy animals. The most used method to express the protein requirements of the dairy animals is the Crude Protein (CP) and Digestible Crude Protein (DCP). The DCP method gives too much weight to non-protein nitrogen (NPN) relative to intact protein. Reference [17] proposed that protein requirement be expressed as available protein i.e. the amount of crude protein of defined biological value that would have to be absorbed from the digestive tract to meet the calculated requirements.

Protein requirement (Table 2.3) is greater in the young, growing and lactating animals. The amount of protein a cow needs depends on her size, milk production and stage of pregnancy. At the first stage of lactation, cow needs more protein due to peak production and body weight loss. Table 2.3 shows the Crude protein requirement of a cow at different stages of lactation.

Table 2.3 : Crude protein requirement of a cow at different stages of lactation

Milk production	Crude protein requirement (%)
Early lactation	16-18
Mid lactation	14-16
Late lactation	12-14
Dry	10-12

(Source: Reference [16]**)**

2.2.3. Fibre

Cows need a certain amount of fibre in their diets to ensure proper rumen functions and to maintain the fat content in milk. Fibre requirements listed are the absolute minimum values. Acceptable levels of Neutral Detergent Fiber (NDF) in the range of 20 to 25% of dry matter. [18] ,(Table 2.4).

Table 2.4 : **The minimum percentage of fiber needed in a cow's diet for healthy rumen function (using three different measures of fiber).**

Fiber measurement	Minimum amount of dietary fiber (% DM)
Neutral Detergent Fibre	20 – 25
Acid Detergent Fibre	19

(Source: Reference [16]**)**

2.2.4. Vitamins

Vitamins are required by the dairy animal to allow proper functioning of the physiological processes of milk production and as constituents of milk itself. There is a dietary requirement for vitamins especially for lactation, but they have a role in synthesis of milk constituents. Green fodders are excellent source of pro-vitamins. To the best of current knowledge, an oversupply of water soluble vitamins will not harm cows since any excess is excreted in urine. However, fat soluble vitamins (vitamins A, D, E and K) are stored in the cow's body and an oversupply of vitamin A or D can cause poisonings or death [19].

- ***Vitamin A***

Vitamin A is also called retinol. It is formed from beta-carotene in the diet. It is essential for good eye sight and needed for tissue and bone formation, growth, milk production and reproduction. Vitamin A maintains healthy epithelium (e.g. the lining of the mammary gland, so deficiencies may increase the incidence of mastitis infections. About 100000 IU of vitamin A is needed per day cow (Table 2.5).Any surplus is stored in the liver up to four months. Vitamin A deficiency is uncommon in cattle that are fed good quality green forages, but may occur on diet high in cereal grains or cereal straw or cattle fed on dry forages for more than six months [5].

- ***Vitamin D***

Vitamin D is formed in the skin when stimulated by sunlight. It is required for calcium (Ca) and phosphorous (P) metabolism in the body. It stimulates Ca absorption in small intestine. It also mobilizes Ca stores from the bones. It can, therefore, be used to alleviate milk fever. Cows need 50 000 IU of vitamin D per day (Table 2.5).Vitamin D deficiencies are very rare in stock fed green forages; however it may become apparent in fully housed cows with little access to sunlight. Vitamin D toxicity (perhaps due to excessive treatment for milk fever) causes calcification of soft tissues, especially the aorta [5].

- ***Vitamin E***

Vitamin E, Selenium and vitamin A all help the cow's immune system to function properly. Immune system fights infections and help cows clean up after calving. Cows need 1 000 IU of vitamin E per day (Table 2.5).Higher amounts may be required around calving time. Vitamin E deficiencies can lead to poor reproductive performance. Retained placenta, metrities, cystic ovaries, low conception rates, stiffness and uncoordinated movement have all been linked to vitamin E deficiency and also may cause early embryonic loss [5].

2.2.5. Minerals

Minerals (Figure 2.1) are inorganic components of the diet are solid, crystalline elements that cannot be decomposed or synthesized by chemical reactions. Dietary mineral sources can be classified based on the concentrations found in an animal's body. The ash content (total mineral content) of an animal's carcass is about 3.5% [19].

Figure 2.1 : Mineral mixture

2.2.6. Essential macro-minerals

Macro minerals or major minerals are found in concentrations that exceed 100 ppm and include calcium (Ca), phosphorus (P), chlorine (Cl), magnesium (Mg), potassium (K), sodium (Na) and sulfur (S) (Table 2.5).The largest amount of Ca, P and Mg are the major minerals found associated with the skeleton system and provide its structural rigidity. Calcium represents about 46% and P about 29% of the total minerals in an animal's body [19].

2.2.7. Essential micro-minerals

Micro minerals are those required in quantities of milligrams per kilogram of dry matter (mg/kg DM), or parts per million (ppm). They include cobalt, copper, iron, iodine, manganese, zinc, selenium and molybdenum. It is very difficult to estimate the mineral requirements of cows because requirement varies according to absorption efficiency of the mineral, production stage and age of the animal, environment and interaction with other minerals.

Mineral deficiencies are less likely if green forages are the major part of the diet. High producing animals may need added minerals into the diets externally [5]. Table 2.5 shows the recommended nutrient content of diets for dairy cattle.

Table 2.5 : Recommended nutrient content of diets for dairy cattle

Cow weight (kg)	Fat (%)	Weight Gain (kg/day)	Lactating Cow Diets Milk Yield(kg/day)					Growing Heifers and Bulls		
400	5	0.22	7	13	20	26	33	3-6 Months	6-12 Months	> 12 Months
500	4.5	0.27	8	17	25	33	41			
600	4	0.33	10	20	30	40	50			
700	3.5	0.38	12	24	36	48	60			
800	3.5	0.44	13	27	40	53	67			
Energy										
NEL, Mcal/kg			1.42	1.52	1.62	1.72	1.72	-	-	-
NEM, Mcal/kg			-	-	-	-	-	1.70	1.58	1.40
NEG, Mcal/kg			-	-	-	-	-	1.08	0.98	0.82
ME, Mcal/kg			2.35	2.53	2.71	2.89	2.89	2.60	2.47	2.27
DE, Mcal/kg			2.77	2.95	3.13	3.31	3.31	3.02	2.89	2.69
TDN, % of DM			63	67	71	75	75	69	66	61
Protein equivalent										
Crude protein, %			12	15	16	17	18	16	12	12
UIP, %			4.4	5.2	5.7	5.9	6.2	8.2	4.4	2.1
DIP, %			7.8	8.7	9.6	10.3	10.4	4.6	6.4	7.2
Fiber content(min)										
Crude fiber, %			17	17	17	15	15	13	15	15
ADF, %			21	21	21	19	19	16	19	19
NDF, %			28	28	28	25	25	23	25	25
Ether extract (%)			3	3	3	3	3	3	3	3
Minerals										
Calcium, %			0.43	0.51	0.58	0.64	0.66	0.52	0.41	0.29
Phosphorus, %			0.28	0.33	0.37	0.41	0.41	0.31	0.30	0.23
Magnesium, %			0.20	0.20	0.20	0.25	0.25	0.16	0.16	0.16
Potassium, %			0.90	0.90	0.90	1.00	1.00	0.65	0.65	0.65

Sodium, %	0.18	0.18	0.18	0.18	0.18	0.10	0.10	0.10
Chlorine, %	0.25	0.25	0.25	0.25	0.25	0.20	0.20	0.20
Sulfur, %	0.20	0.20	0.20	0.20	0.20	0.16	0.16	0.16
Vitamins								
A, IU/kg	3200	3200	3200	3200	3200	2200	2200	2200
D, IU/kg	1000	1000	1000	1000	1000	300	300	300
E, IU/kg	15	15	15	15	15	25	25	25

(Source: Reference [16]**)**

2.3. Problem identification

Before selecting the suitable cattle feed for Sri Lanka, it is mandatory to find the basic problems related to the cattle feed technology. Hence will be predicted the feed type, production process and the good raw materials etc.

2.3.1. Main problem

- How to make feed blocks?

2.3.2. Engineer's perspective

- Size of the block :Cross section

  30cm*30cm to 20cm*20cm

  Dia 25cm to Dia 20cm

- Weight should be 1.5kg to 3kg
- Used for recommended recipes from NLDB
- Production capacity should be 100 blocks/h to 125 blocks/h

2.3.3. Dependant problems

- What type of block forming method used for making blocks?
- How to mechanized block forming method?
- How to automate mechanized system?
- How raw materials are prepared?

- How raw materials are feed into the block maker?
- How to get output as blocks?
- How to post process the output?

2.3.4. Secondary problems

- What type of power source is used?
- What is the required capacity of the power?

2.4. Agricultural by-products used in feed block technology

In the animal production system, convectional feeds like forages, cereals, milling by-products and oil cakes are given to both ruminants and non-ruminants. The term non-convectional feed (NCF) of non-convectional feed resources (NCFR) refers to the feed ingredients which are hither to not been used for animal feeding. It is a relative term and may differ from country to country and region to region, and time to time in the same country. For example, paddy straw (Figure 2.2) is a convectional feed in northern part of Sri Lanka for proper feeding of livestock. Normally up to 60% of dry matter intake of dairy cows is from crop residues in many countries. These residues exhibit low voluntary intake (1.5% of body weight) as a result of the high bulk of digesta in reticulorumen, and slow rate of digestion. A certain portion of ration includes cereals and their by-products, oil cakes and mineral supplements to fulfill the daily nutritional requirements. The cereal grains like maize, sorghum, millet etc. are rich in energy mostly in starch and low in fiber, Phosphorus and calcium.

Figure 2.2 : Agriculture waste

2.4.1. Paddy straw

Paddy straw (Figure 2.3) is the by-product left after the removal of ripe seeds by threshing and consist of stem and leaves of plants. This product is extremely fibrous, rich in lignin and of extremely low in nutritive value, containing about 3% crude protein and 40% TDN(Table 2.6).The utilization of paddy straw by ruminants is possibly the most efficient means of conservation of this residue to overcome problems of pollution through slow breakdown or burning [19].

Figure 2.3 : Paddy Straw

2.4.2. Rice milling by-products

There are several types of rice milling by-product use for feeding cattle to fulfill their daily nutritional requirement. The extraction rate and quality of rice milling by-product depend on type of mill, milling rate, variety of rice and whether parboiled or raw. The approximate extraction rates of by-products are; hull - 20%, bran - 10%, polish - 3%, broken rice - 1-17%. Rice bran refers to the aleurone and other layers removed from rice during milling. Rice polished includes layers of inner seed coat and some endosperm material. It is low in fiber and high in starch and fat. A mixture of bran and polish is called rice pollard. Rice bran/polish is sometimes adulterated with ground rice husk thus reducing its feeding value. Rice bran/polish (Figure 2.4) is high in fat therefore palatable to animals. Rice fat contains a high concentration of linoleic acid (5.8%), an essential fatty acid and also it is good source of energy. Quality of rice bran gets deteriorated very rapidly during storage because of high fat content [20].

Figure 2.4 : Rice bran

2.4.3. Coconut poonac

Coconut poonac (Figure 2.5) is a major agro industrial by-product available in Sri Lanka. After oil extraction, 35-40% of copra (by weight) remains as poonac. Coconut poonac contains 20-22% crude protein with low concentration of essential amino acids (Table 2.6). Metabolizable energy content of coconut meal is also low due to its high fiber content. Coconut meal will continue to be an economically important source of protein in many Asian and Pacific countries where other supplements are not commonly available. Because of high fat content coconut poonac is prone to rancidity [20].

Figure 2.5 : Coconut Poonac

2.4.4. Molasses

The feed value of molasses (Figure 2.6) for cattle is widely recognized all over the world. Molasses is concentrated water solutions of sugars, hemicelluloses and minerals obtained usually as a by-product of various manufacturing operations involving the processing of large amounts of the juices or extracts of plant materials;

E.g. Cane, beet, citrus, wood. Especially cane molasses is used in cattle feeding to improve ration acceptability and rumen microbial activity, to reduce dustiness of ration and as a binder for pelleting or block formation, as a source of energy and as an unidentified factor. Molasses is used in amounts not exceed about 10-15% of the ration [21].

Figure 2.6 : Molasses

Table 2.6 : **Nutritional status of Agricultural waste materials**

Feed type	Dry matter (%)	Crude protein (%)	Crude fiber (%)	Ether extract (%)	Ca (%)	P (%)	TDN (%)
Paddy straw	90	3.1	28.9	1	0.33	0.07	40
Rice bran	87	12	13	15	0.71	1.4	40.2
Coconut poonac	87.7	20	12.3	7.5	0.4	1	53
Molasses	73.7	5.5	0	0.4	0.9	0.1	20
Wheat flour	88	10.4	11.6	1.01	0.04	0.42	39.2

(Source: Reference [22]**)**

2.4.5. Mineral-rich ingredients

- ***Urea***

Ruminants are able to synthesis protein from non-protein nitrogen (NPN) through microbial action in the rumen. Thus, NPN may be used as a substitute for protein in ruminant rations. However, when so used, it must be fed along with a readily fermentable carbohydrate source. In pure form, it contains 46.67% nitrogen, giving of a crude protein equivalent value of 281 (45×6.25). In order to be used by rumen microbes, it must first be hydrolyzed to form carbon dioxide and ammonia. This hydrolysis is accomplished by the action of an enzyme, urease secreted by the rumen microbes. Urea (Figure 2.7) toxicity may result when fed excess quantity. Adult animals should be fed at the most 100 – 120g/day. According to the recommendations, 20 – 25g urea per 100kg body weight can be given along with readily fermentable carbohydrates so as to keep the rumen pH below a level of 6.Urea should be fed at least 2 - 3 times daily. They can be incorporated in the concentrate mixture or in water and sprinkled over dry roughages along with molasses [21].

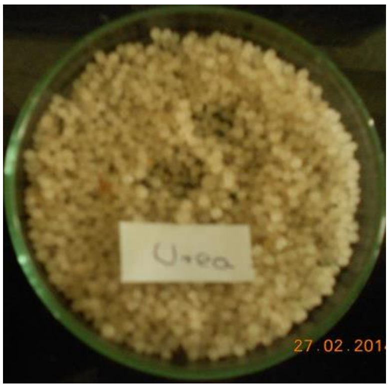


Figure 2.7 : Urea

- ***Cement***

Mainly cement is manufactured by incorporated lime or calcium oxide from limestone, chalk, shells, shale or calcareous rock, Silica (SiO_2) from sand, old bottles, clay or argillaceous rock, alumina (Al_2O_3) from bauxite, recycled aluminum, clay, Iron (Fe_2O_3) from clay, iron ore, scrap iron and fly ash and gypsum ($CaSO_4.2H_2O$) through milling and crushing process. In livestock industry cement use as a mineral supplement, feed binding material or as a dough strengthener.

- ***Salt***

Salt (Figure 2.8) is made up of sodium and chloride, but it is also an ideal carrier for a variety of essential trace minerals like Calcium, magnesium, selenium for lactating cows [21].

Figure 2.8 : Salt

2.5. Preparation of blocks

For preparation of cattle feed blocks it is required to find the production flow process which is used for common feed block making and also it is required to compare the pros and cons.

2.5.1. Process flow chart

Figure 2.9 shows the common production process flow chart required to make the cattle feed block.

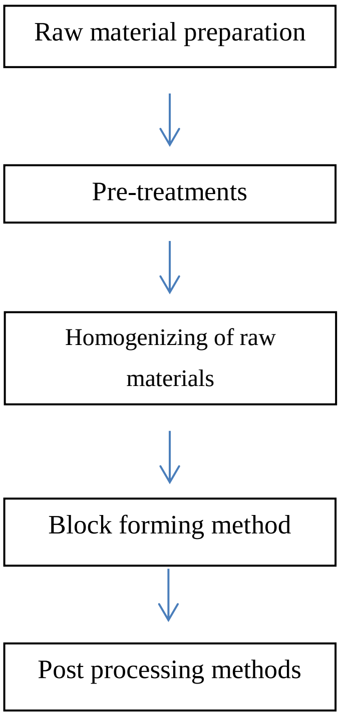


Figure 2.9 : Process flow chart of making solid feed block

2.5.2. Raw material preparation

Raw material preparation is mandatory for making the feed blocks. Hay, coconut poonac, rice polish, rice brand, Dhal Dust, Soya bean meal, Maize, Mineral mixture, Vitamins etc are the required raw materials. Hay is defined as the cut and dried grass and similar agricultural residues used as animal food during the dry seasons the availability of hay is less which generate economic losses to livestock holders. The surplus of hay after the harvest season could be made available during the dry season. Since, storing hay without further processing is problematic due to its huskiness and the insect attack presence of moisture, apart from the high handling and transport cost. So preparation of hay it required to cut into small pieces. For cutting these hay can be used hay cutters, available in the market. Motorized hay cutter in NERDC is shown in Figure 2.10, other types of hay cutters are shown in Figure 2.11 and the cut hay is shown in Figure 2.12.

Figure 2.10 : Motorized Hay Cutter

Figure 2.11 : Different types of hay cutters

(Source: www.alibaba.com)

Figure 2.12 : After cutting the Hay

Hay wanted to dry after cutting or chopping. Drying can be used direct sun drying or use solar dryer (Figure 2.13) or an oven dryer. Considering above methods sun dry is the low cost reliable method than the solar dryer. The oven drying is not suitable for drying hay. Because after drying it could be flammable and higher temperatures it destroys the nutrition.

Figure 2.13 : Solar dryer

Other raw materials wanted to crush and some wanted to grind. As an example the coconut poonac and maize etc. wanted to crush into small pieces. Di-calcium phosphate, minerals wanted to ground. The crushing machines are shown in Figure 2.14 and the grinding machine is shown in Figure 2.15.

Figure 2.14 : Crushing machine

Figure 2.15 : Grinding machines

(Source: www.lukemachinery.com)

2.5.3. Raw material mixing

After preparation of raw material it is mandatory to homogenize by using mechanized or manual mixture. In the mechanized mixture (Figure 2.16) could add liquid materials using top funnel and solid materials could be add using top hopper. Could be used concrete mixture without using this type of horizontal mixture machine.

Figure 2.16 : Raw material mixer developed by NERDC

2.5.4. Introduction of feed-block technology

Block feeding is an effective mechanism for delivering daily required nutrients to dairy cattle in most developed countries. Success or failure of a feed block/tube program will depend on the availability of forages. As with other supplements, blocks and cubs widely vary in their cost, ingredient composition, nutrient content, storage requirements and consumption characteristics. Blocks and cubs generally can be divided into four categories based on the manufacturing method used. They are Fodder (pressed) blocks, Pelletized blocks, chemically hardened blocks and low moisture (cooked) blocks and cubs. Advantages of using blocked feed are shown in Table 2.7.

Table 2.7 : Advantages of using blocked animal feeds

	Loose Bulk Agro Residue Material	Blocked Agro Residue Material
Loading Time	10 person/8hrs	3 person/4hrs
Unloading Time	5 person/5hrs.	3 person/3hrs.
Wastage	5 to 10% wastage in loading, unloading & transport. In 9 ton truck only 6 ton transported.	Zero transit & handling wastage at each stop or transfer point. Full truck load can be transported.
Space Utilization	Bigger space less quantity stored e.g. in 10x10 room 8 ton. Can be stored only in enclosed.	More than 2.5 times can be stored in comparison of loose Fodder. e.g. in 10x10 room 20 ton. Open & Close stored (Close areas can be utilize For more cattle).
Storage Limitation	Should Not be Safe in open storage.	Can be stored in both open area & close storage With minimum care required.
Annual Purchase Cost	Rates are volatile so cost comes high	Controllable, if stored max post harvesting
Purchase Season	Not in rain season	Easily available round the year
Health	Causes allergy & Lung disease due to dust.	It is in packed in poly bags so there is no health hazard. Helps in maintaining hygiene & worker’s health.
Supervision	Required	Easy Accountable
Dust Segregated	Not Possible	Dust content reduces while baling.
Fodder Quality	Chances of sand mixing. For increasing weight and margin.	Dust free atmosphere is achieved for handling & storage.
Life	-----	Dry blocks packed almost eliminate the chance of Bacterial growth.

2.5.5. Pelletised blocks

This technology is particularly useful for hard materials. Also it is a useful technology for regions in which feed milling plants are operating at a low capacity and biomass is available in abundance. Straws that are highly lignified with hard fiber can be easily crushed and converted into pellets. Straws of wheat, soybean, mustard and cotton can be used for production of straw-based pelleted feed. The feed pellets may contain 30–35% crushed straw,10–12% molasses, 35–40% de-oiled rice bran, 10–15% oilseed meals, 1% each of urea and common salt, 1.5% calcite powder and 1% mineral mixture. The production cost of these pellets could be in the range of Rs.10 to 15 per kg in year 2016 where the availability of the biomass and other feed materials is not a constraint. If 6–8 kg of these pellets is fed per animal per day, it is possible to support body maintenance and 3–4 kg per day milk production.

Depending up on the level of milk production, level of roughage component can be reduced and that of concentrates increased. For example, for the animals yielding about 15kg of milk per day, straw-based pellets may contain 15–20% straw, 25% crushed grains,30% oilseed meals, 10–15% rice polish, 10% molasses, 2% mineral mixture and 1% each of common salt and calcite powder.

In northern states of India, a large numbers compound cattle feed making plants exist. These plants are running at less than 50% of their capacities and in Punjab State of India alone an additional 1500 tons of pelleted feeds can be produced per day if full capacities of the plants could be utilized. Agencies in the straw deficit areas need to get in touch with such private entrepreneurs in the areas of surplus, well in advance, for securing the Pellet mill for enriched Straw surplus biomass for the production and supply of straw-based pelleted feed. Some of the farms in India are producing and storing biomass in this manner. During the recent floods in eastern parts of India, straw-based pelleted feed was sourced from some of such feed mills. During the scarcity periods densified straw-based pellets are produced and supplied by some of the millers in northern India. Straw-based pellet making plants (Figure 2.17) are now being installed at Malabar union and Kerala Livestock Development Board in southern India with the technical support of NDDB [23].

Sri Lanka have the pelletized mills in several areas where those are located in Pelwatte Dairy industries-Pelwatte, CIC Feed mills-Ekala, New Hope-Ekala etc. These plants provide the animal feed to farmers.

Such pellets could also be used for creation of buffer stock in large quantity because the bulk density of the pellets exceeds 600 kg per cubic meter. It is very difficult to make densified feed blocks from the highly lignified biomass as such blocks would tend to disintegrate if not packed immediately after pressing. Major benefits of densified feed pellets are Highly lignified biomass can be enriched and densified in the form of pellets which otherwise is difficult to handle, Densified pellets are more palatable than the straws/crop residues, storage and transportation costs decrease due to high bulk density, Fire hazards are reduced, Shelf life of the biomass increases. Usually, the biomass with soft stem is considered to be more suitable for making densified feed blocks while the biomass that is more hard and lignified can be handled more effectively through the pellet making technology. Density of the straw-based feed blocks is about 450 kg per cubic meter against 600 kg per cubic meter for pellets.

Pellets can be stored in bulk while blocks always need wrappers or high density polyethylene bags to retain their shape. During long storage sometimes blocks tend to swell back. Also, mechanical aeration and fumigation in bulk stored pellets is easier as compared to blocks when densified biomass is required to be stored as buffer stock for longer duration of time (2–3 years) [23].Pelletized block (Figure 2.18) is supplementary animal fodder. So fulfilling the diet it wants to supply the other ingredients like hay, green grass etc. This is the main disadvantage of the palletized fodder.

Figure 2.17 : Pellet making machine

(Source: Reference [23])

Figure 2.18 : Pelletized animal feed

(Source: www.gcmec.com)

2.5.6. Fodder block

The fodder block is a pressed block which contains the all ingredients of a meal required for animals specially cows, goats, sheep etc. The making of feed block requires proper processing and can be manufactured on a large scale in a factory, using a hydraulic press. The process of densification causes physical attachment of the minute concentrate particulate matter to fibrous straw particles with the help of a binder, so much so that there is hardly any opportunity for the animal to select the feed components.

The ingredients of fodder blocks can be divided into major and minor components. The major components are forage and concentrate, added in different ratios, depending upon the level of production while the minor component constitutes micronutrients and feed additives. The forage part is generally the crop residues such as wheat, paddy straw, sorghum stalk, sugarcane tops, and maize Stover. In hilly areas, even the non-conventional forages like forest grasses and tree leaves have been used in place of crop residues. This has been done in the North–Eastern region of India, especially in Nagaland, where the feed blocks, based on tree leaves and dried forest grasses have been successfully fed to Mithun, a bovine species resembling buffaloes [24].Some studies shown that sugarcane bagasse can be used economically as an alternative source of forage to replace 30% of wheat straw in feed block, without any adverse effect on the growth of crossbred calves [25].

This not only brings uniformity to the feed, but also increases the palatability of the straw based feeds and minimizes the feed wastage. The process of densification may also slightly improve the digestibility of straw, as each straw particle has the concentrate component attached to it through molasses, which may facilitate the cellulolytic microbes to grow faster and enhance fiber degrading activity in rumen. Although the rate of release of energy and nitrogen in the rumen from fodder blocks depends on the nature of ingredients used, the feeding of fodder blocks generally allows a synchronized supply of nutrients to rumen microbes including rumen anaerobic fungi, resulting in their enhanced growth [26]. Ensuring the synergy between the nutrient demand of rumen microbes and the release of adequate level of the nutrients for their optimal growth is the hallmark of straw based densified complete feeds. Since Straw based densified total mixed ration the ingredients in fodder blocks remain more or less the same over a longer period of time, the daily supply of these blocks having uniform composition also ensures a steady supply of nutrients to microbes, which brings stability in the rumen eco-system for optimal microbial fermentation. This also results in uniform supply of precursors for milk and muscle (meat) synthesis, and consequently may enhance efficiency of nutrient use. In Figure 2.19 shows that the feeding of the fodder blocks to the animals and the Figure 2.20 shows the compressed fodder block.

Figure 2.19 : Feeding fodder blocks

(Source: Reference [26])

Figure 2.20 : Fodder blocks

(Source: Reference [23])

- ***Advantages of the fodder block technology***

The densified complete feed block technology offers a variety of benefits to the farmers and the feed manufacturers. This could be a promising technology for the regions where there is a perennial shortage of green forage and the dry forage is also in short supply and is being transported from outside. Based on the available literature, our own experiences, and from the feed-back received from farmers who fed these blocks to animals, the following advantages have been identified [27].

a) A promising way to feed a balanced ration to ruminants

Normally it is difficult for illiterate or semi-literate farmers to compute a balanced feed for the animal. In fact, except at some organized farms, practice of feeding balanced rations is almost non-existent in many developing countries. By feeding fodder blocks to an animal a balanced feed, one can expect improved nutrient supply and their utilization, leading to improved animal productive and reproductive performances.

b) An efficient nutrients delivery system

While feeding, the animal is given less opportunity to select more digestible feed components. This reduces the feed wastage and thus is an efficient delivery system of supplying feed nutrients to the animal which in itself is economically advantageous to the farmer.

c) Time as well as labour saving

Feeding of this to animals is a simple, hassle-free exercise which reduces the expenditure on labour with respect to feeding is reduced by 30–40%. Being a readymade feed, the farmers find it easier to feed them. According to a farmer view it takes just 20–30minutes to feed 20 animals per person, as against two hours for feeding the same number of animals in a conventional manner. This is a clear advantage to farmers who generally look after the feeding and management of dairy animals, spending best part of their lives in drudgery, by cutting, collecting and transporting huge loads of grasses from forest or road-sides on daily basis.

d) Feed as blocks require lesser storage space

The process of densification increases the bulk density of the straw based feed and at the same time it reduces its volume. Accordingly lesser storage space is required to store the bulky feed, especially straw. The farmer could use the saved space for other farm activities.

e) Densified feed cheaper and easier to transport

Over filling of straws to the open vehicles is hazardous and causes large number of accidents on the roads. Since the feed blocks occupy lesser space and volume than the original components in the uncompressed state more feed (by weight) can be accommodated and transported within the same space. This makes the transportation of feed block much easier and cheaper than the straw.

f) Better way to manage crop residues and reduce pollution

In many parts of Asia, straw worth millions of dollars is also burnt in the field after harvesting of the grains. If the residual straw left in the field is mechanically collected and converted into feed blocks, not only this valuable feed resource could be effectively used, but the emission of greenhouse gases, caused by burning of straw could also be avoided. In addition, the high temperature generated during the burning of straw kills the soil microorganisms, affecting adversely the soil fertility. Also there is less dust pollution when the feed is transported as blocks rather than as loose straw.

g) Improved productive and reproductive performance

This feed has a positive effect on production as well as reproduction of the animals. Based on the feedback collected from farmers in Uttra Khand (India), who fed straw based complete feed blocks to their growing and lactating animals, it was observed that the growth rate of calves could increase by 25–35%, while the milk yield could increase by 15–20%. [27].There could also be some increase in fat content of milk. After feeding, the milk yield of the animal persists at a higher level over a longer period, resulting in increase in total lactation yield. This may be explained by the fact that the feeding of straw based complete feed blocks eliminates any day to day dietary fluctuations thus providing the rumen microbes a constant supply of the same type of feed/substrates, bringing stability in the rumen environment and making ruminant system overall more efficient.

Because of the faster growth rate, could result in early maturity and early age at first calving for the animals. The feedback collected from Uttra Khand(India) farmers that the age of heifers at first calving may decrease by about4–6 months [27], which is a distinct advantage in lowering the cost of rearing animals. The farmers reported that the feeding of these blocks reduces calving interval and animals generally conceive within three months after calving. As a result of these positive changes, overall reproductive efficiency of the animal also increases. Apart from optimum supply of energy and protein through complete feed block, the animals get proper amount of minerals and vitamins as per their requirement, which enhances reproductive efficiency.

h) Lesser methane emission from animals

The inclusion of concentrate to straw diet is known to reduce methane emission from the rumen. The emission of methane can be reduced by 10–15%, simply by feeding a balanced diet prepared by mixing straw, concentrate ingredients and minerals [28].

i) Better health status

The optimum supply of nutrients and micro-nutrients has a positive impact on the maintenance of good animal health. The feeding of these blocks provides immune-protection against infectious diseases and also decreases the occurrence of metabolic and reproductive disorders. Consequently, this may also reduce the farmer’s expenditure on treatments and on maintaining proper health of the animals.

j) Feed banks can be set up as a pre-emptive disaster management measure

With the advent of feed block technology, it is possible to set up feed banks nearer to feed deficit areas. Because of easy handling, transportation and storage of the straw based feed blocks, the technology could improve preparedness against natural calamities, and save animals from hunger and death during these emergency situations. The blocks can even be air lifted to the remotest places to avert disasters.

k) Scope for value addition

There is substantial room for improving the quality of straw based complete feed blocks as a vehicle for medicine or neutraceutical administration. Its value addition could be a continuous exercise through extended research, trying different supplements, newer feed additives, neutraceuticals, anthelminths and herbal extracts to improve their overall nutritional quality. However, it has to be ensured that the non-nutrient additives are used within the specified limits, so that it do not cause any major dilution of macro or minor nutrients in the feed blocks, which could reduce nutritional quality of the blocks.

l) Better economic returns through providing stability in feed and milk prices

The benefit provided by easier storage of feed blocks makes it possible to supply uniform quality of the feed throughout the year, with lesser price fluctuation, as against the large price fluctuation and irregular supply of straw and other feed ingredients in different seasons. This could also have an impact on stabilizing milk prices, irrespective of seasons and could produce milk of uniform quality. Better performance of the animals obtained on feeding fodder blocks would obviously bring better returns to the farmer.

- ***Fodder block forming machines***

a) Manual machines

Manual compaction machines (Figure 2.21) are used to make the fodder blocks. Due to its low compaction pressure the foamed block size get larger and softer. So transportation of these blocks is difficult. As a cottage industry it is a low cost technology and these blocks provides animals a balanced diet of energy, nitrogen, minerals, and vitamins.

Figure 2.21 : Manual block making machine

(Source:http://lcccrsp.org/2014/10/east-africa-scholar-margaret-syomiti-selected-to-present-at-the-united-nations-sharefair-2014)

b) Mechanized machine

This a manual operated hydraulic compactor (Figure 2.22) which uses to form the fodder blocks. Considering the machine operation firstly raw materials were loaded to the hopper after the end door was at closed position. Then the compression hydraulic cylinder starts to compact the raw materials. After compression was finished the end door was open meanwhile the foam block was pushing out. Production capacity of the machine is 20 number of 3kg blocks per hour and it was required one operator and the two casual workers to loading and unloading per shift.

Figure 2.22 : Medium scale manual operated hydraulic fodder block making machine

(Source: http://www.new-ag.info/en/focus)

The compaction machine foam a block of 50 per cent chopped straw or cane tops blended with 39 per cent concentrate and 11 per cent molasses, which increases palatability and acts as a binding material [29].

Another block making machine (Figure 2.23) is used to blocks the paddy straw where the paddy straw harvesting machines convert straw into small pieces which are collected into big tarpaulin bag. These bags are then taken to the fodder block processing units. These units make 150 to 165 blocks per hour. Fodder blocks are made in 5.5 kg and size 30x30x10 cm and it required not more than 5 inches size cut hay [30].

Figure 2.23 : Hay block making machine

(Source: Reference **[30]**)

2.5.7. Chemically hardened blocks and cubs

Chemical blocks (Figure 2.24) are manufactured by combining liquid and dry ingredients into slurry. The slurry is dispensed into cardboard containers or plastic tubs and allowed to cure. The block hardens as a result of chemical reactions between water and metal oxides such as calcium oxide or magnesium oxide. Hardness of the block or tub is regulated by altering the concentration of metal oxides. Once hard, chemically set blocks do not change shape.

Normally in Sri Lankan context it uses cement as a chemical binder. These blocks used as supplementary meals which contain more minerals like urea, salt etc. Farmers are used cement block making machine to form these blocks.

Advantages are chemical process blocks use many ingredients common to both liquid and dry feed manufacturing. Formulation is more flexible than the other processes. Major barriers are chemical blocks may have a high ash (mineral) content. Ingredients such as magnesium oxide may limit intake because of their objectionable flavor. These blocks can deteriorate during prolonged inclement weather, especially if packaged in cardboard [31].

Figure 2.24 : Chemically harden block

(Source:www.fleetfarm.com)

2.5.8. Low moisture (cooked) cubs

This is the most expensive block manufacturing process, requiring specialized blending, evaporating and packaging equipment. Liquid ingredients are heated to 240-280^{o}F (cooked), subjected to a vacuum to remove moisture, combined with dry ingredients in a blender and poured into rigid containers. It results, in uniform consumption rates when used in intensive grazing environments.

However, there are few disadvantages. There are limited packaging options because these blocks tend to absorb moisture from the air. Due to the consistency of the products and their tendency to change shape, containers must be stored in the upright position. In addition, the process is somewhat restrictive in the proportions of dry ingredients that can be incorporated. Specialized manufacturing equipment is also required [31].

2.5.9. Post processing of feed blocks

Protection of the moisture is the step for post processing of the formed blocks which can reduce the fungus attacks. So sealing of these blocks can be put in to a sacks or polythene bags or warp using stretch films (Figure 2.26) or shrink wrapping (Figure 2.25). Pelletized feed is always packed into sacks. And others can be use above all methods. The blocks are put into polythene bags are more reliable and low cost. Shrink warping is required to put into the oven which is costly than the normal polythene bagging.

Figure 2.25 : Sink wrapping

(Source: www.alibaba.com)

Figure 2.26 : wrap using stretch films

(Source: www.amazon.com)

2.6. Chapter Summary

This chapter discussed the literature related to cattle feed available in the market. It illustrated the available manufacturing process flow for making cattle feed and also it found four type of common cattle feed which including pelletizing, fodder block, low moisture cooked cubs and chemically harden blocks. The raw material preparation, pretreatments, homogenizing and post processing steps were common for each type of feed. Also it discussed the livestock industry, agro climatic zones, dairy farming systems, available feed resources, feeding strategies in Sri Lanka, nutritional requirement of dairy cows and issues find for cattle feed.

3 METHODOLOGY

This chapter discusses the methodology regarding cattle feed block preparation and making machinery. It includes selection of block type which suit to Srilankan context using brainstorming session, selecting a suitable ration form literature and small experimental analysis, finding a block forming parameters by using experiment and hence finding the block forming parameters. Finally design of the industrial machine for making solid feed blocks.

3.1. Brainstorming session conducted for finding the suitable block forming methods by using Agro-waste

Brainstorming session was conducted in NERD Centre for finding the suitable block forming methods with using the agro waste by inviting the experts. This opportunity was also used to clarify the need analysis before proceed the project.

3.1.1. Organisations/Institutes invited for the brainstorming session:

1. MILCO
2. Sri Lanka-Libya Agriculture & Livestock (Co) Ltd
3. Supper Feed Pvt Ltd
4. Udupussellawa Agro Pvt Ltd
5. CIC Agri business Pvt Ltd
6. New Bernards Animal Feed Pvt Ltd
7. Hayleys Agriculture Holdings Ltd
8. National Livestock Development Board
9. New hope Pvt Ltd
10. Pelwatte Diary industries pvt Ltd

3.2. Types of recipes

The recipe is a mixing ratio of the ingredients which are used to make the feed. The proportion of the straw and concentrate in the block varies with the type of animal to which it is to be fed. As a survival ration for use during natural calamities and disasters, the straw component could be very high. To meet the challenges during emergency situations, straw blocks have generally the following composition: 86 parts straw, 10 parts molasses, 2 parts mineral mixture, 1 part urea and 1 part salt, which could meet the maintenance requirement of the animals. The proportion of straw for animals yielding up to 5–10 kg milk per day should be reduced to 60%, for 10–15 kg milk per day, up to 50% and for 15–20 kg milk per day, up to 40%. A similar kind of range has to be maintained in the crude protein (CP) content of the block, varying from 7–14%, and in the total digestible nutrients (TDN) content varying from 45–65%. A superior quality block of 14 kg has sufficient nutrients for the production of 20 kg of milk per day. Since buffaloes are heavier in weight and their milk having a higher fat content, a 15 kg block of the similar composition is suggested for buffaloes with respect to above three categories.

The ingredients of the concentrate mixture are oil cakes/meals as protein source, molasses, grains, grain by-products as energy sources and supplements such as bypass protein or bypass fat. Bypass nutrients can be added for the higher yielders to enhance the direct supply of amino acids and fatty acids to the host animal as concentrated protein and energy sources respectively. The third component provides strategic and catalytic supplements, such as micronutrients and other feed additives, for example vitamins, minerals, bentonite (binder), probiotics, enzymes, antioxidants, immune-protective agents, antitoxins and herbal extracts, among others.

The varied role of these components in the feed block is to increase the productive and reproductive efficiency of the animal, enhance its immuno-protective ability, reduce helminthic load and decrease ruminalmethanogenesis [23].

3.2.1. Selecting a suitable ration

Four experimental feed blocks were formulated by combining different agro waste materials according to the NRC recommendations. After mixing raw ingredients with binders, it was compressed into a block according to the Recipes used for formulation of feed blocks at laboratory scale. Table 3.1 shows the recipes used for Formulation of feed blocks at laboratory scale. Figure 3.1 and Figure 3.2 shows the prepared samples for making solid feed block.

Table 3.1 : Recipes used for formulation of feed blocks at laboratory scale

Raw ingredients (%)	Recipe 01	Recipe 02	Recipe 03	Recipe 04
Straw	70	60	70	65
Coconut poonac	5	10	5	10
Rice polish	3	10	10	5
Dhal dust	5	3	1	3
Maize	3	3	-	3
Premix	0.5	0.7	0.5	0.5
Salt	0.5	0.3	0.5	0.5
Urea	2	2	2	2
DCP	0.5	0.5	0.5	0.5
Lime	0.5	0.5	0.5	0.5
Molasses	10	10	10	10

Figure 3.1 : Sample preparation

Figure 3.2 : Prepared samples

Three samples from each feed block (B1, B2, B3 and B4) were analyzed for dry matter, crude protein, crude fiber, fat, calcium and phosphorus according to the

Association of Official Analytical Chemist AOAC (1998). The chemical analysis was done at the Veterinary Research Institute, Gannoruwa, Peradeniya.

3.3. Solution sets

Solution sets (Table 3.2) for block forming of cattle feed, it must require the solutions for dependent problems. As methodology it considers the methods for preparation of raw materials, pretreatments of raw materials, Homogenizing of raw materials (proper mixing), Suitable block forming method and post processing of the foamed blocks.

Table 3.2 : Solution sets

Solutions

Raw material preparation	Pre treatments	Homogenizing of raw materials	Block forming method	Post processing methods
Cutting of hay Manual cutting Cut using mechanized machine	**Drying** Sun drying Using Oven Dryer Using Solar dryer	**Proper mixing of raw materials** Using manual method (mixing with shovel etc.) Using concrete mixture Using NERDC Developed mixer	**Pelletizing**	**Put into the Sack**
Crushing of raw materials (maize,coco nut poonac etc.) Manual crushing (beating) Crush using machine			**Foaming of Fodder block** Manually foaming Foaming by mechanized machine	**Put into the polythene**
Grinding of raw materials (Di-calcium phosphate, minerals etc.) Manual grinding (mortar and pestle) Grind using machine			**Foaming chemically harden**	**Wrap using stretch films**
			Foaming Low moisture (cooked)	**Shrink warping**

Considering the above flowchart of solution sets it was found that 360 independent paths to foam compressed solid feed block. So obtaining the proper path for making solid block it can use screening technique.

- Screening of raw material preparation

  This block making processes is a bulk method. That means this is not a laboratory method of foaming of solid feed blocks. So that the manual methods used for cutting, crushing and grinding is not ethical/reliable. Each cutting, crushing and grinding wanted to use machineries.

- Screening of pretreatments.

  For pretreatments of the raw materials it is required to dry the materials. So considering the method of drying the oven drying is more expansible than the other methods. So the cheapest method is sun drying. Considering the sun drying and the solar dryer, the solar dryer is costly (capital cost) than the sun drying. So the both sun drying and solar dryer, solar dryer is more reliable in considering the different weather conditions.

- Screening of homogenizing of raw material

  Homogenizing of raw materials it can be use either manual mixing or mixing using concrete mixture or mixing using NERDC developed mixture. Manual mixing is not proper method due to bulk block foaming. So it can be either use concrete mixture or NERDC developed machine. Proper mixing was done on using NERDC developed machine.

- Screening of block forming methods

  For screening of the suitable block forming method it was used the weighted score method with ten relevant persons feedbacks. This wanted to screen the optimum Block foaming methods either can use palletizing or fodder block foaming or Foaming chemically harden blocks or Foaming Low moisture (cooked) cubs. After the average scores it was found the suitable block forming method with verification of the results of the brainstorming method.

- Post processing methods

  Considering the post processing methods pack into a sack is always used for pelletized materials. Others it is difficult to put into sacks. So fodder blocks, chemically harden blocks and Low moisture (cooked) cubs can be packed using stretch warping, shrink warping and polythene bags. So from above methods shrink warping is involving the high cost than stretch warping and the put into the polythene bag is the lower one of above. Packing by Polythene is the optimum.

3.4. Experimental setup

3.4.1. Preparation of raw materials

Hay (straw) is cut using the hay cutter within the range of 2-4 inches size available in NERDC. Cut paddy straw and the cutting machine are shown in Figure 3.3.

Figure 3.3 : Cut paddy straw and the cutting machine

The crushing (Figure 3.4) of the poonac and maize is done by using the crushing machine available in NERDC.

Figure 3.4 : Crushing of poonac and the maize

Grinding of the minerals could be used for grinding machine. This experiment is used ground minerals purchased from the outside.

3.4.2. Pre-treatment of raw materials

For pretreatments of the raw materials it is required to dry these materials. Sun drying (Figure 3.5) is used for drying the above raw materials up to required moisture conditions.

Figure 3.5 : Sun drying of some raw materials

3.4.3. Homogenising of raw materials

NERDC developed machine is obtaining the proper homogenizing of raw materials. But in this case it is required small samples for finding the proper block forming parameters (compression force). According to that the samples are prepared by using manual mixing method.

3.4.4. Forming of fodder blocks

Analysis of compression force it is used small scale manually operated hydraulic press (Figure 3.6) which maximum applied force is 30T load.

Figure 3.6 : Manually operated hydraulic press

- ***Required surface pressure analysis for block foaming***

In this case it was used different shapes of molds which was same cross section of square and circular. For as samples it was used four recipes used for NLDB and three levels of moisture samples (10%, 20%, 30%, 40% and 50% of moisture levels).The moisture measurement was taken by using moisture meter and it was very difficult to maintain exacts moisture levels due to inhomogeneity of the raw materials. Five different load levels (different surface pressures) (Table 3.3) were applied for each above samples. For taking the results two hundred times block forming was done. The block height was taken by using the steel ruler with the fabricated wise when just after the block was removed, after one hour left and after one day left. The measured block heights were tabulated as shown in the observations tables.

Note:

Square mold size: 80mm*80mm*300mm

Circular mold size: Inner Dia 90mm*300mm

The same cross section area of the mould were selected for this experiment which is applied the same surface pressure to each blocks.

Table 3.3 : Applied pressure to blocks during the experiment

Applied load in hydraulic press/(MT)	Applied surface pressure (throughout the block cross section) /(kg/cm^2)
5	78
10	156
15	234
20	312
25	390

Figure 3.7 shows the block forming using the manual hydraulic press, the Figure 3.8 shows the formed cylindrical block and the Figure 3.9 shows the formed square block using manual hydraulic press.

Figure 3.7 : Block foaming using square and cylindrical molds

Figure 3.8 : Foamed blocks

Figure 3.9 : Square shape foamed blocks

3.4.5. Post processing

After taking the measurements some samples were packed into the polythene bags as shown in Figure 3.10.

Figure 3.10 : After doing the post processing to the blocks

3.5. Results

3.5.1. From the brainstorming session

From the brainstorming session conducted by NERD Centre (Chapter 3.1) the following results were obtained. As current requirements and the potential demands, Most of the dairy farmers in Sri Lanka mainly depend on naturally available forages for feeding purposes. Especially during the drought, natural forages were not enough for feeding. Currently most agricultural waste materials were not used in proper manner under animal feed production in Sri Lanka. So commercial cattle feed prices and concentrates prices were high, Therefore manufacturing of cattle feed block, incorporating different combination of agro waste was more important with affordable prices.

- ***Process of cattle feed block preparation***

It has been clearly identified that the process of block preparation should definitely be followed by a proper supervision in order to keep the required hygienic level of the cattle feed to prevent cattle from diseases which could affect the milk yield.

- ***Selection of raw materials***

Most of the agricultural waste materials can be used as raw ingredients of cattle feed block. Mainly,

- Forage materials:Hay grasses (Guneia, CO3, Napier, etc.)
- Hay legumes (Gliricidia, Ipilipil, etc.)
- Concentrates (Soya bean meal, Rice polish, Coconut poonac, Dhal dust, Maize)
- Binding materials-Molasses, Cement
- Mineral materials (Salts, Shell grids, Lime stones, Commercial mineral mixture)

- ***Quality checking of raw ingredients***
  - Visual inspection
  - Physicochemical properties (pH, Moisture content, Nutritional status, Anti nutritive factor content)
- ***Pretreatments for raw ingredients***
  - Chopping- Forage materials
  - Heat treatments- Soya bean meal
  - Boiling- Molasses
- ***Mechanical mixing and block forming***
  - Shape of the block- Square shape, it is easy to store
  - Weight of the block- 1.5-2kg
- ***Packaging***
  - Under sealing package
- ***Storage***
  - Blocks are stored in a dry cool place, in order to maintain 18% moisture content inside the package
- ***Determination of shelf life of the product***
  - Durability of the product is increased by adding some chemicals like $CuSO_4$ at level. A sub sample is taken from each treatment once a week and microbial count by Total Plate Count Method.
- ***Machine development***

Machines are identified as required for

- material preparation -Chopping machine, grinding machine
- material mixing – Stirrer machine
- Block making

These machines should be,

- Single phase or Three phase power supply
- Semi-automatic operation
- Investment capacity for machinery is around two million LKR

As per the views of the participants it has been identified that the most of the cattle farmers are currently using cattle feeds such as natural forages in fresh form and concentrates as dry powder form. But they have emphasized that the importance of a solid cattle feed block and its ability of creating the opportunity of rearing cattle at limited space even at urban areas and during forage scarcity periods of the year.

Nutritional status, hygienic conditions of the feed block mainly affect to the final dairy production in both quantity and quality. Main target group of machinery development is commercial level dairy farmers and cattle feed suppliers to maintain the quality of the final product.

3.5.2. Selection of the suitable block forming method

From the chapter 3.2, the average scored values were found and those were tabulated in Table 3.4.For marking the weighted values the licket scale (Figure 3.11) was used.

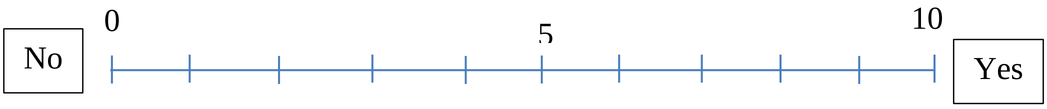


Figure 3.11 : Licket scale

Table 3.4 : Average scored values for screening the block forming method (Analytical comparisons)

	Pelletizing	Fodder blocks	Chemically harden blocks	Low moisture (cooked) cubs
Balance diet	6.2	8.5	3.8	4.4
Used agricultural wastes (Green leaves, paddy straws, Grass etc.)	2.6	9	1.5	1.7
Used other by products from factories (rice polished, coconut poonac, maize etc.)	7.8	9	6.8	6.8
Used minerals, vitamins etc.	6.7	8.5	7.2	6.7
Without used unwanted ingredients for cattle (eg. cement)	7.4	9	2.4	4.7
Not importance to used powered materials	3.9	8.3	2	3
Increasing of storing capacity	7.9	8.9	6.6	6.5
Good transportability	7.1	8.5	6.5	6.3
Percentage (%)	**62**	**87**	**46**	**50**

From above results it was found that the high potential for making fodder block and required machinery. Others were less potential for cattle feed.

3.5.3. Selection of the recipes

From the chemical analysis it was determined that the average proximate composition, minerals of cattle feed blocks (B1, B2, B3, B4) prepared using different agricultural wastes Table 3.5.

Table 3.5 : Proximate composition & minerals of feed blocks

Composition	Recipe 01	Recipe 02	Recipe 03	Recipe 04
Dry matter (%)	93.9	90.2	91.7	94.3
Crude protein (%)	13.3	16.6	14.7	18.4
Ether extract (%)	2.4	3.1	2.1	2.3
Crude fiber (%)	29.62	28.12	29.80	28.84
Ca (g/kg)	9.1	8.3	7.9	9.2
P (g/kg)	2.7	3.4	3.3	3.8

Feed block 04 (B4) contained high amount of crude protein (18.4%) compare to other feed blocks. At the first stage of lactation, cow needs more protein due to peak production and body weight loss. Crude protein requirement of cows categorized under early lactation, mid lactation and late lactation are 16-18%, 14-16% and 12-16% respectively [16].Crude fiber contents were not much different among feed blocks (28 - 30%). Generally, straw contains 28.9% crude fiber by weight [32]. Higher Calcium and Phosphorus contents were recorded in block 04 (B4).

3.5.4. From the experiment

Following the above methodology the test were carried out and the observation were tabulated in Table 3.6, Table 3.7, Table 3.8 and Table 3.9).Sample weight (200g) is constant during the entire test.

Table 3.6 : Observations for recipe B1

Applied Load from press (MT)	Moisture percentage of the sample	Block cross section	Length of the block just after block foaming (mm)	Length of the block after one hour (mm)	Length of the block after one day (mm)
5	50%	Square	150	185	210
		Circular	150	180	210
	40%	Square	145	170	190
		Circular	140	165	190
	30%	Square	120	150	170
		Circular	120	150	170
	20%	Square	105	125	140
		Circular	105	120	140
	10%	Square	95	110	130
		Circular	90	110	130
10	50%	Square	145	180	200
		Circular	140	180	200
	40%	Square	140	150	180
		Circular	135	150	175
	30%	Square	105	130	150
		Circular	110	130	145
	20%	Square	90	100	120
		Circular	100	105	120
	10%	Square	80	90	110
		Circular	105	105	105
15	50%	Square	140	170	180
		Circular	140	170	180
	40%	Square	120	130	155
		Circular	120	125	145
	30%	Square	90	100	130
		Circular	90	100	125
	20%	Square	60	80	95
		Circular	65	85	95
	10%	Square	60	75	95
		Circular	60	80	90
20	50%	Square	120	155	160
		Circular	120	150	155
	40%	Square	100	125	130
		Circular	95	125	125
	30%	Square	85	105	120
		Circular	85	100	120
	20%	Square	65	80	95
		Circular	60	85	90

	10%	Square	65	80	95
		Circular	60	80	90
25	50%	Square	120	140	150
		Circular	115	140	145
	40%	Square	100	125	130
		Circular	95	120	125
	30%	Square	85	105	120
		Circular	85	100	120
	20%	Square	65	80	95
		Circular	60	85	90
	10%	Square	65	80	95
		Circular	60	80	90

Table 3.7 : Observations for recipe B2

Applied Load from press (Ton)	Moisture percentage of the sample	Block cross section	Length of the block just after block foaming (mm)	Length of the block after one hour (mm)	Length of the block after one day (mm)
5	50%	Square	160	195	220
		Circular	160	195	215
	40%	Square	140	180	200
		Circular	135	180	200
	30%	Square	130	150	180
		Circular	125	150	175
	20%	Square	115	125	160
		Circular	110	120	155
	10%	Square	105	115	130
		Circular	105	115	125
10	50%	Square	150	185	200
		Circular	150	180	200
	40%	Square	140	170	180
		Circular	135	165	180
	30%	Square	115	130	160
		Circular	120	135	150
	20%	Square	95	110	130
		Circular	100	110	130
	10%	Square	90	100	120
		Circular	90	105	120
15	50%	Square	145	180	185
		Circular	145	180	185
	40%	Square	135	155	170
		Circular	130	150	170

	30%	Square	100	115	140
		Circular	105	120	135
	20%	Square	70	90	105
		Circular	70	90	100
	10%	Square	65	80	100
		Circular	65	80	100
20	50%	Square	140	160	175
		Circular	140	155	170
	40%	Square	120	135	150
		Circular	120	135	145
	30%	Square	95	115	130
		Circular	100	120	125
	20%	Square	70	85	100
		Circular	70	85	100
	10%	Square	70	80	100
		Circular	70	80	100
25	50%	Square	130	140	150
		Circular	130	135	145
	40%	Square	100	120	140
		Circular	105	115	135
	30%	Square	95	110	125
		Circular	95	110	120
	20%	Square	70	80	100
		Circular	70	80	100
	10%	Square	70	80	100
		Circular	70	80	95

Table 3.8 : Observations for recipe B3

Applied Load from press (Ton)	Moisture percentage of the sample	Block cross section	Length of the block just after block foaming (mm)	Length of the block after one hour (mm)	Length of the block after one day (mm)
5	50%	Square	150	170	180
		Circular	145	170	180
	40%	Square	140	160	175
		Circular	140	155	170
	30%	Square	120	140	160
		Circular	120	140	160
	20%	Square	110	130	130
		Circular	105	125	125
	10%	Square	105	100	120
		Circular	100	100	115

10	50%	Square	140	165	170
		Circular	140	160	170
	40%	Square	130	155	160
		Circular	130	155	160
	30%	Square	100	125	145
		Circular	105	130	140
	20%	Square	90	100	110
		Circular	90	100	110
	10%	Square	80	90	105
		Circular	80	90	100
15	50%	Square	135	160	170
		Circular	135	160	165
	40%	Square	125	140	150
		Circular	120	135	150
	30%	Square	95	110	125
		Circular	100	115	125
	20%	Square	65	80	90
		Circular	70	80	90
	10%	Square	65	75	90
		Circular	65	75	90
20	50%	Square	125	155	160
		Circular	120	155	160
	40%	Square	115	130	140
		Circular	110	130	140
	30%	Square	90	100	115
		Circular	100	105	115
	20%	Square	70	80	90
		Circular	70	80	90
	10%	Square	70	80	90
		Circular	65	80	90
25	50%	Square	120	150	160
		Circular	120	150	155
	40%	Square	105	125	130
		Circular	100	120	125
	30%	Square	90	100	115
		Circular	90	100	115
	20%	Square	70	80	90
		Circular	70	80	90
	10%	Square	65	75	90
		Circular	65	75	90

Table 3.9 : Observations for recipe B4

Applied Load from press (Ton)	Moisture percentage of the sample	Block cross section	Length of the block just after block foaming (mm)	Length of the block after one hour (mm)	Length of the block after one day (mm)
5	50%	Square	175	185	225
		Circular	170	180	215
	40%	Square	160	175	195
		Circular	160	170	190
	30%	Square	135	150	180
		Circular	135	150	180
	20%	Square	115	130	155
		Circular	115	125	150
	10%	Square	110	110	140
		Circular	105	110	140
10	50%	Square	170	180	190
		Circular	170	180	190
	40%	Square	150	170	180
		Circular	150	170	180
	30%	Square	125	140	170
		Circular	130	145	170
	20%	Square	100	120	140
		Circular	105	120	135
	10%	Square	90	105	130
		Circular	95	110	125
15	50%	Square	160	175	180
		Circular	155	170	175
	40%	Square	140	160	175
		Circular	135	160	175
	30%	Square	105	120	140
		Circular	110	125	135
	20%	Square	70	85	100
		Circular	75	85	100
	10%	Square	65	80	100
		Circular	70	85	100
20	50%	Square	135	155	170
		Circular	130	155	165
	40%	Square	130	150	160
		Circular	125	145	160
	30%	Square	100	120	135
		Circular	105	120	135
	20%	Square	75	85	100
		Circular	70	80	105

	10%	Square	70	80	100
		Circular	70	80	95
25	50%	Square	120	140	150
		Circular	120	140	145
	40%	Square	110	130	145
		Circular	105	120	140
	30%	Square	95	110	130
		Circular	100	105	130
	20%	Square	70	80	100
		Circular	70	80	100
	10%	Square	70	80	100
		Circular	70	80	95

According to the above observations graphs was plot for find the optimum required surface pressure with respect to the moisture content of the raw materials and the block shape.

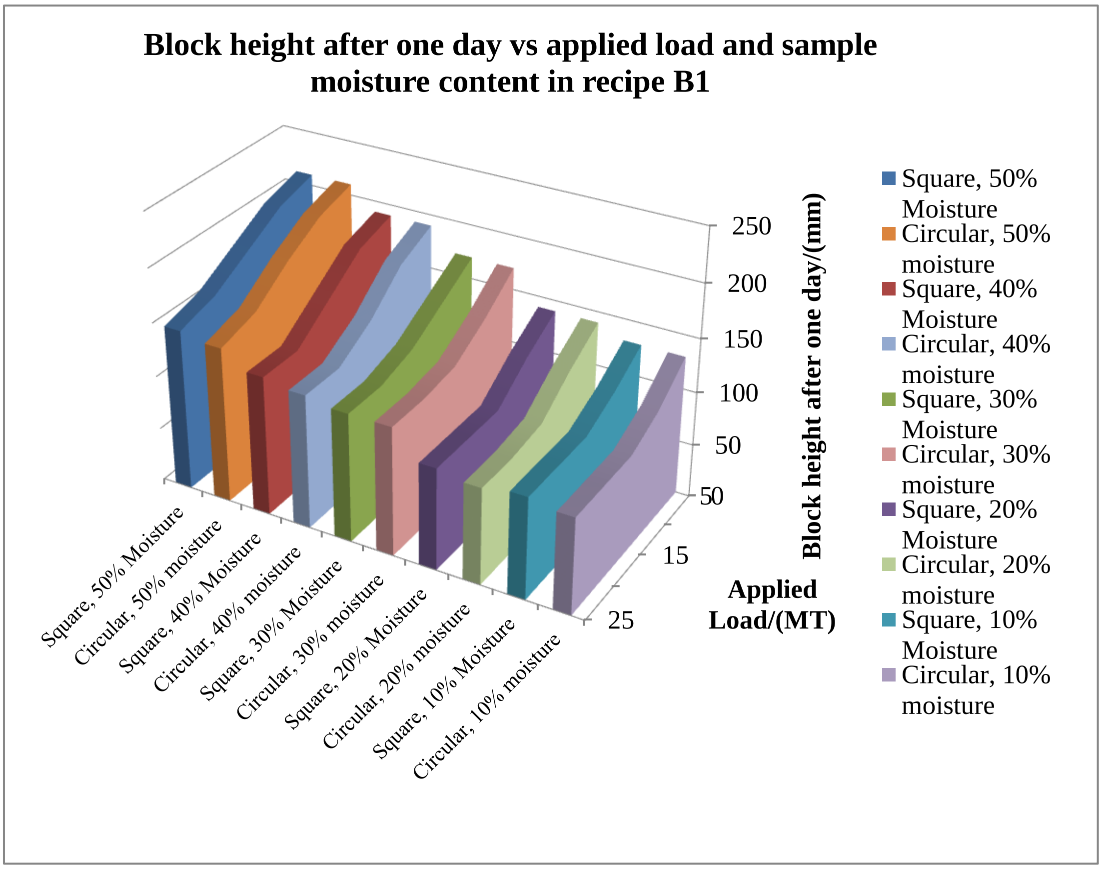


Figure 3.12 : Block height after one day vs applied load and sample moisture content in recipe B1

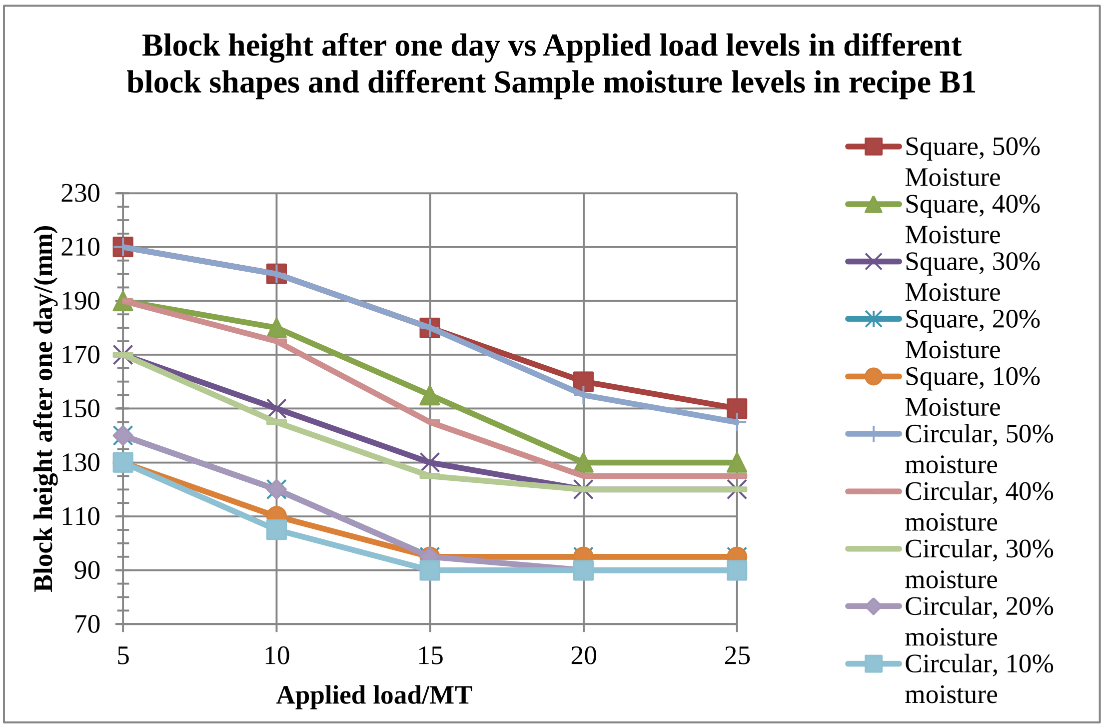


Figure 3.13 : Block height after one day vs Applied load levels in different block shapes and different Sample moisture levels in recipe B1

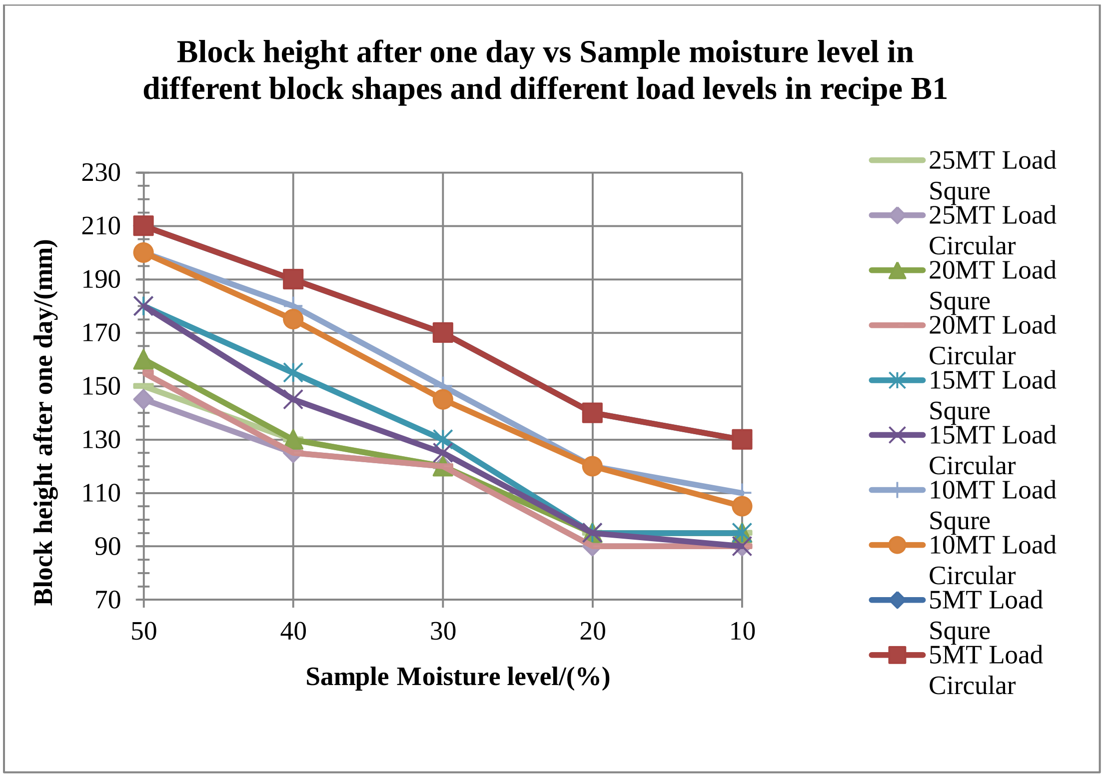


Figure 3.14 :Block height after one day vs Sample moisture level in different block shapes and different load levels in recipe B1

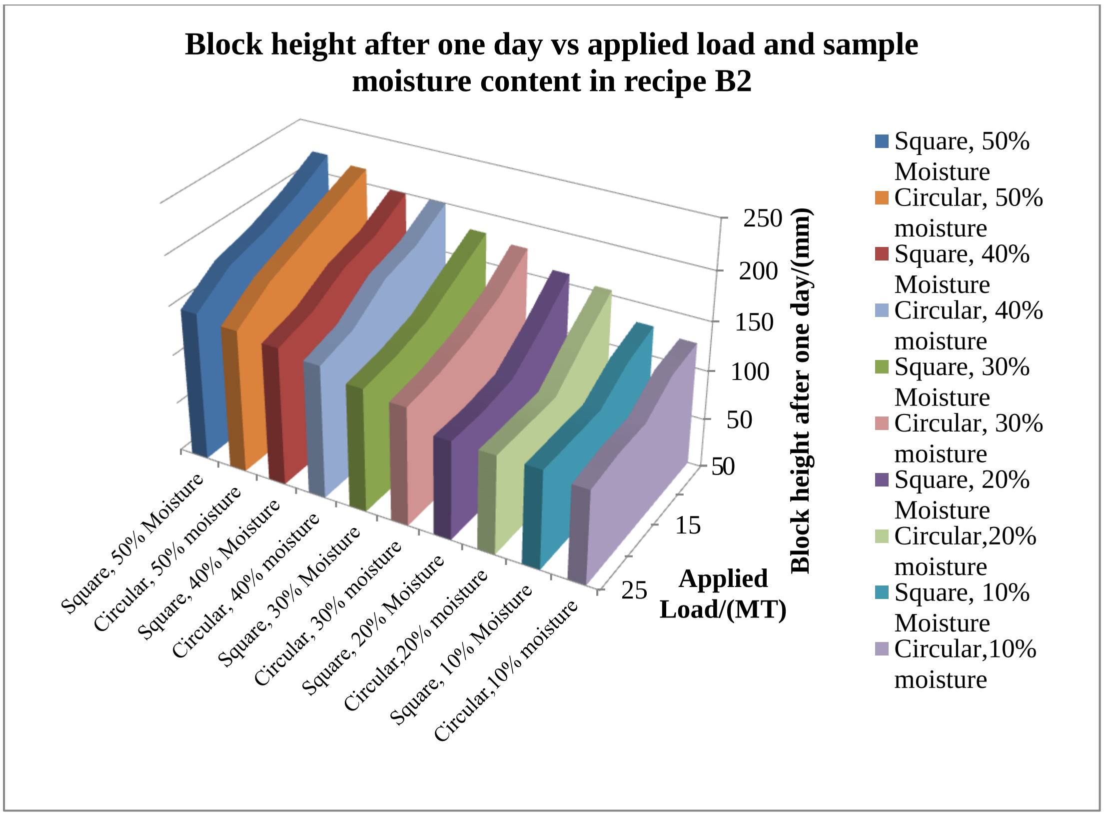


Figure 3.15 : Block height after one day vs applied load and sample moisture content in recipe B2

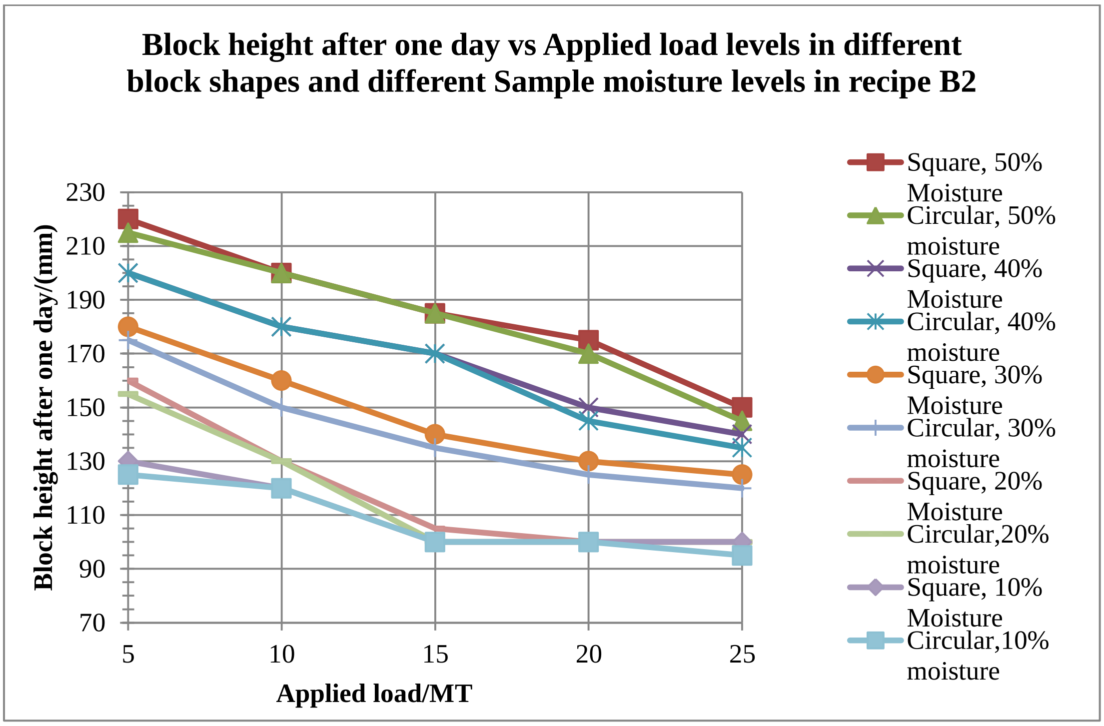


Figure 3.16 : Block height after one day vs Applied load levels in different block shapes and different Sample moisture levels in recipe B2

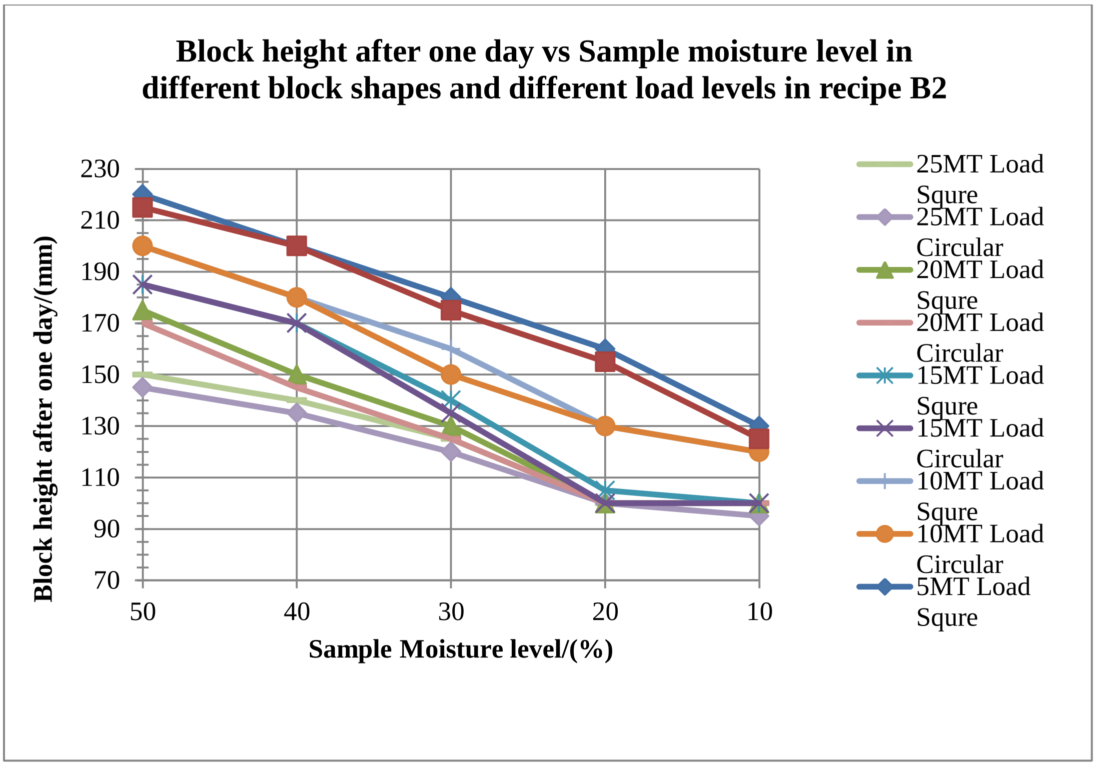


Figure 3.17 : Block height after one day vs Sample moisture level in different block shapes and different load levels in recipe B2

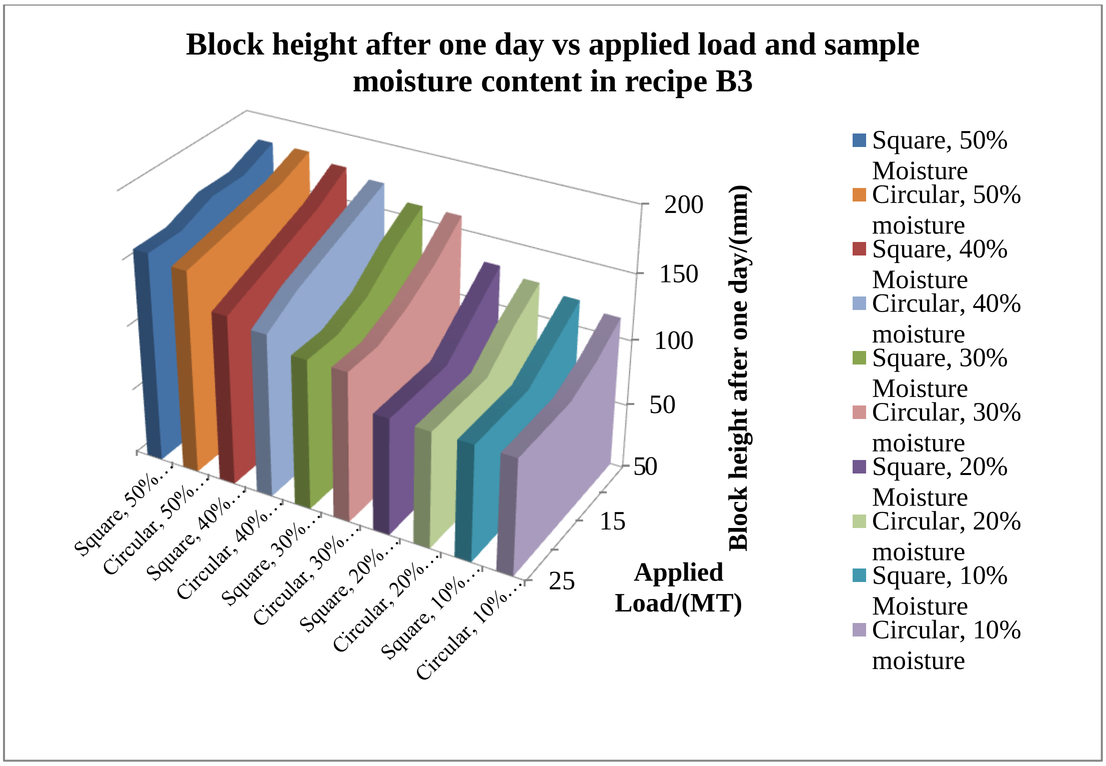


Figure 3.18 : Block height after one day vs applied load and sample moisture content in recipe B3

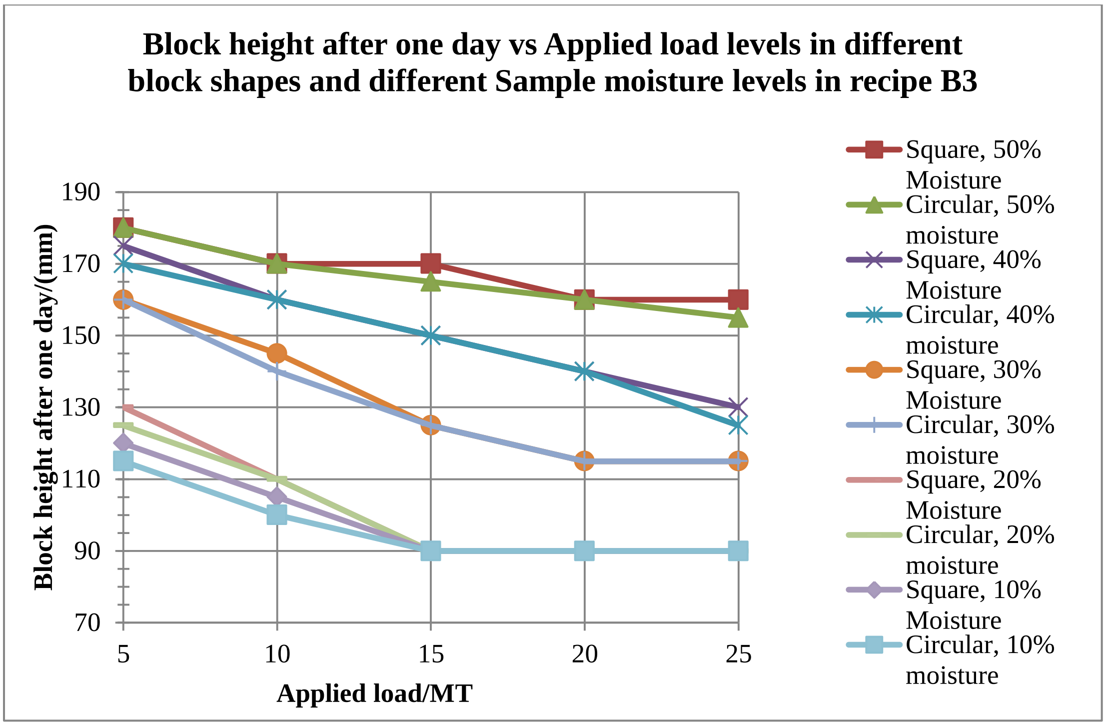


Figure 3.19 :Block height after one day vs Applied load levels in different block shapes and different Sample moisture levels in recipe B3

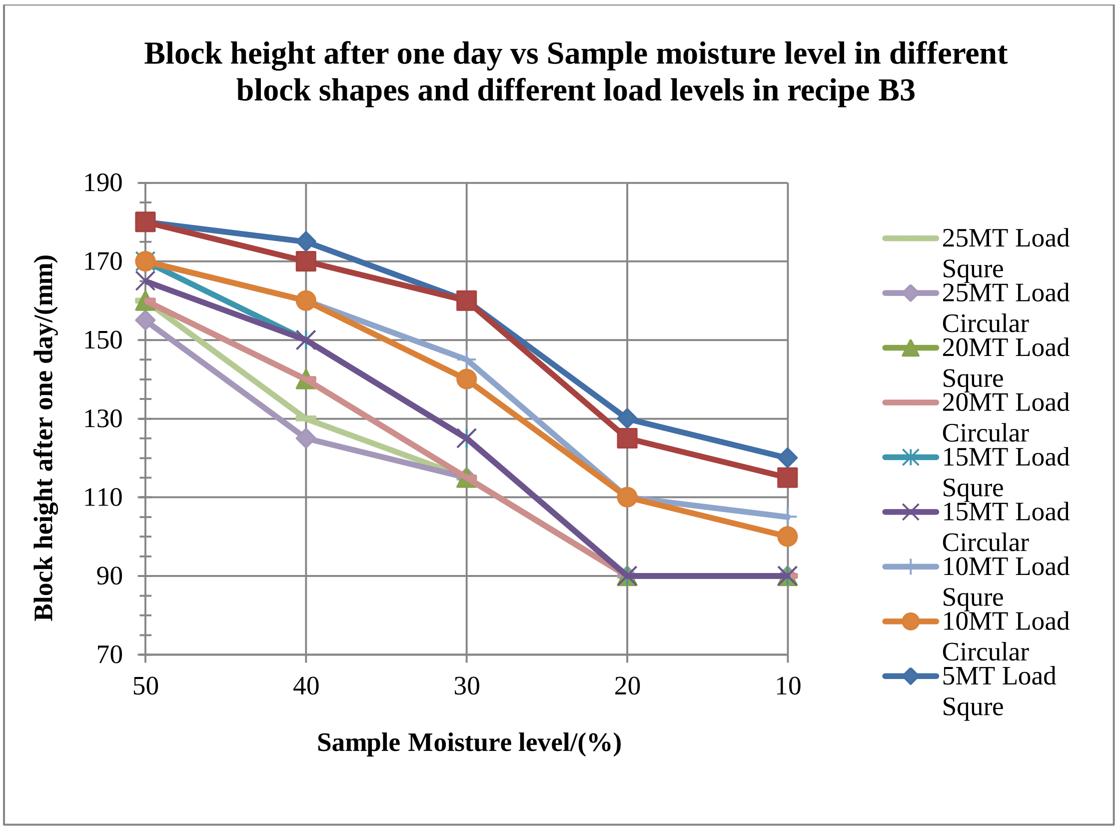


Figure 3.20 :Block height after one day vs Sample moisture level in different block shapes and different load levels in recipe B3

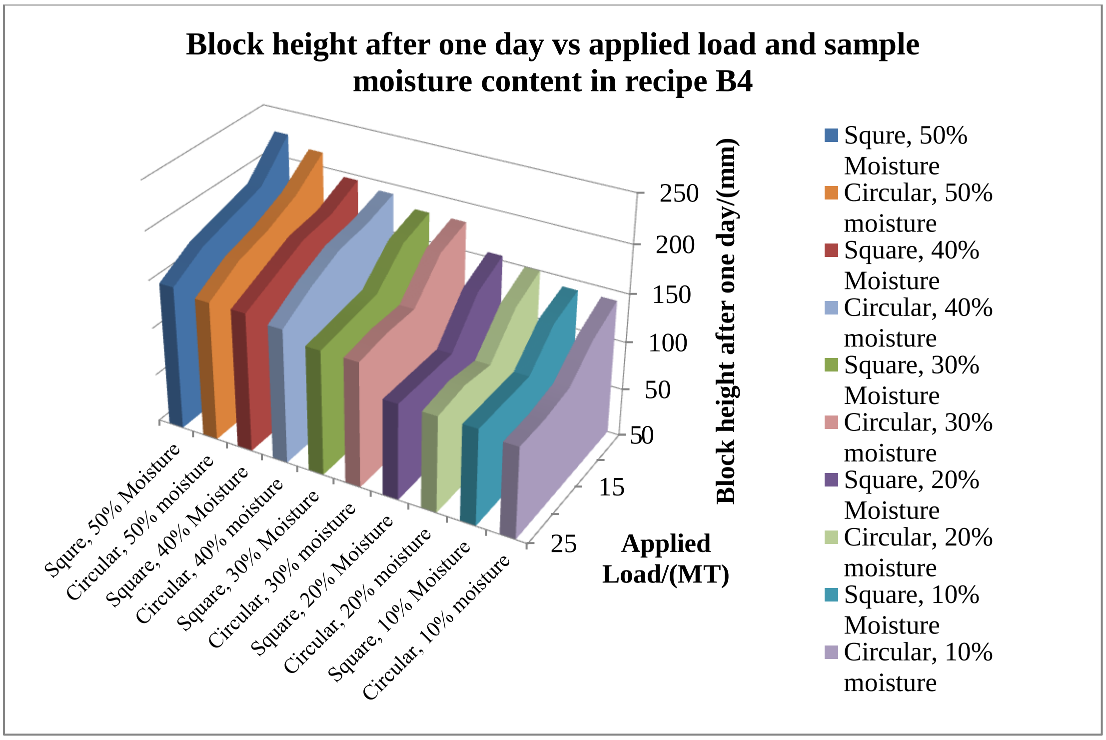


Figure 3.21 : Block height after one day vs applied load and sample moisture content in recipe B4

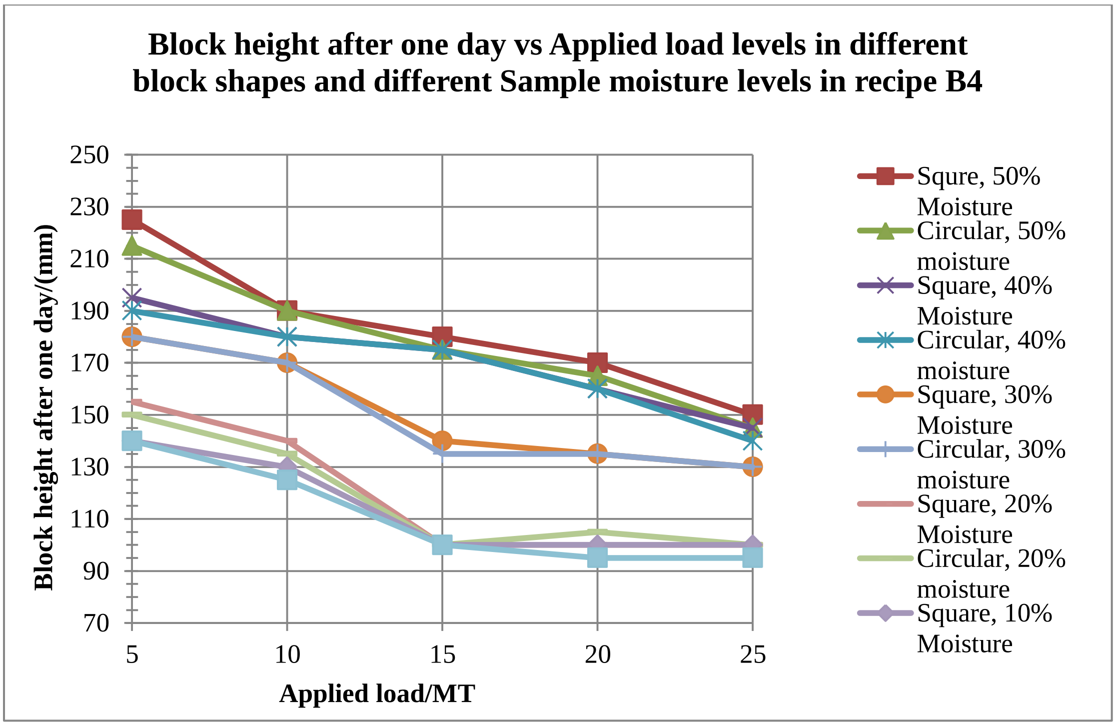


Figure 3.22 :Block height after one day vs Applied load levels in different block shapes and different Sample moisture levels in recipe B4

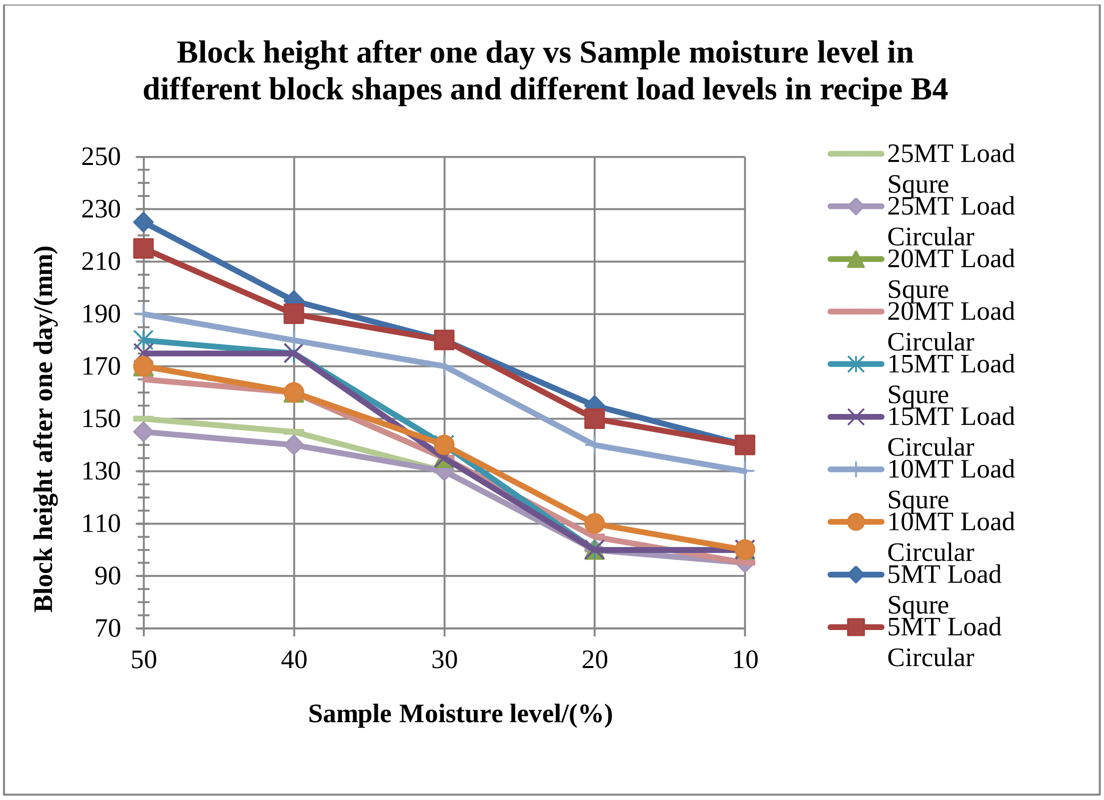


Figure 3.23 :Block height after one day vs Sample moisture level in different block shapes and different load levels in recipe B4

The Figure 3.12, Figure 3.15, Figure 3.18 and Figure 3.21 shows the block height after one day against the applied load and the moisture content of the samples where further illustrations are included in the other graphs. The Figure 3.13, Figure 3.16, Figure 3.19 and Figure 3.22 show the block height after one day against the applied load levels in different moisture samples. The Figure 3.14, Figure 3.17, Figure 3.20 and Figure 3.23 show the block height after one day against the moisture content of the samples in different load levels.

Considering the Figure 3.13, Figure 3.16, Figure 3.19 and Figure 3.22 its clearly shows the higher applied load levels indicated the lower block heights for each moisture content samples and also 15MT to 20MT loads with lower moisture levels, the heights of the block are same.

Considering the Figure 3.14, Figure 3.17, Figure 3.20 and Figure 3.23 its clearly shows the lower moisture contents samples are indicated the lower block height for higher applied loads and also less than 20% moisture samples and 15MT to 20MT applied loads, the block height are maintain the same.

3.6. Discussion

3.6.1. For brainstorming session

According to the ideas of participants, they have accepted that this naval feeding method exist a huge potential for the increase the total milk production of Sri Lanka. So it is required to develop a process and machineries to prepare cattle feed block with incorporating agricultural waste materials.

3.6.2. Selection of suitable block forming method

Normally Mineral blocks are the chemically harden blocks and it is a supplementary feed for the animals. As chemicals it used the Portland cement and some binding agents. And also Low moisture (cooked) cubs is like a mineral blocks and it is used steam to block foaming. This could destroy some vitamins due to high temperature. So considering the above two these block making is not viable.

Comparing palletizing and the fodder blocks, pelletized materials include agricultural waste (Rice polish, coconut poonac etc.) but it is included small amount of hay (Hay is includes paddy straws, grass, leaves etc). So for animals balance diet it would require more than 60% of hay. If it uses palletized materials for animals for completeness of the diet it would want to supply hay or green leaves. Considering the fodder blocks it includes all the ingredients for balance diet. According to the above screening method that obtains the height marks and the above factors fodder block making is the best for use in drought seasons also.

3.6.3. Selection of the recipes

Cattle feed block is an effective solution for supplementing nutrition to dairy cattle during forage scarcity periods. They can be made from locally available materials with the main ingredients being paddy straw, coconut poonac, rice polish, dhal dust, maize and molasses. Other ingredients such as minerals, salt and vitamins should be added to balance the nutrition requirement of cattle. According to our laboratory experiments, Block 4 (B4) contained higher crude protein, Calcium & Phosphorous contents than other three feed block samples [33].

3.6.4. For experiment

The above all results (chapter 3.5.4) clearly shows the block shape is independent for making solid feed blocks in lower moisture and the higher applied loads. But in the higher moisture and the lower applied loads its shows the circular shape block is quit compressed than the square shape. And also the fabrication of the door less compaction machine the square shape mould machine is easy and low cost compared to the circular shape mould.

Considering the different recipes, it is shows that the higher fiber (hay) content samples are more compressible than the lower Fiber (hay) content samples.

In practically lower moisture content samples can be store for long time periods. Because low moisture levels, the fungus growth rate is lower than compared to higher moisture levels.

From above observations it can be summarized as, the less than 20% moisture content samples and 15MT to 20MT (Surface Pressure 234 kg/cm^2 to 312 kg/cm^2) applied loading ranges are the optimum parameters for making solid feed blocks with square shape.

3.7. Conclusion

It was found that the fodder block making is the best option for making cattle feed in Srilankan context. The recipe for foaming fodder block should include 60% of hay and other nutrition's according to the age of the cattle. The shape of the block is independent in less than 20% moisture raw materials. The fodder block forming maximum surface pressure is 312kg/cm^2. But it was shown that the same results for surface pressure is vary in between 254 kg/cm^2 to 312 kg/cm^2.Fulfilling the above block forming conditions the compaction machine was designed.

3.8. Chapter summary

In this chapter it was discussed the feed block making technology and selected the suitable cattle feed block suit to Srilankan context. From experimental analysis it was found that the block forming parameters such as forming surface pressure, block shape, moisture content etc. for designing the compaction machine.

4 DESIGN , FABRICATION AND RESULT VERIFICATION

This chapter discusses the design and fabrication of the solid feed block making machine. Hence prove that the parameters found from the above chapters (Chapter 2 and 3) and the results of the fabricated machine. Design includes the design of hydraulic system, design of an electrical control system, design of structural elements etc. And also includes the field testing details once the machine is fabricated. Finally compare the design details and the field testing details.

4.1.1. Introduction

Conclusion of the chapter 2 and 3 it was found that fodder (solid) block making is the better, viable solutions for animal feed. And also square shape is more useful with 1.5kg -2kg of block. For developing the machine, it should be semi-automated (only raw materials loading and unloading is the only manual work) to address the labour scarcity. So fulfilling above conditions the following machine was developed.

4.1.2. Details of the proposed machine

Semi-automated two stage compressing machine (Figure 4.1) is proposed to make solid cattle feed block. The raw material volume is fairly large and its loading is fairly difficult. So eliminating the above issue it has been design two stage compression compactor machine.

- Production capacity : 90 blocks/h to 120blocks/h
- Block size : Square block 200mm*200mm cross section
- Weight of a block : 1.5kg -2kg
- Power consumption : 12kW three phase
- Compression technique : Electrically controlled hydraulic system.

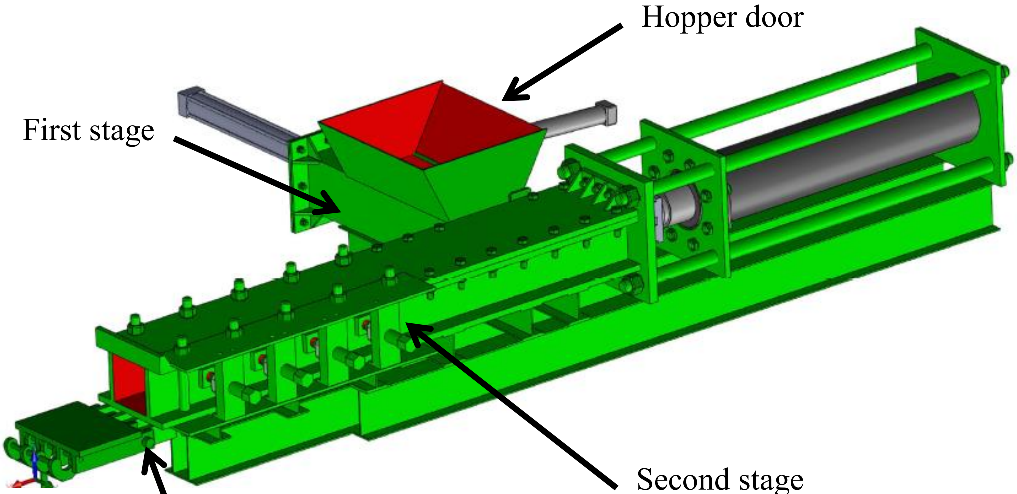


Figure 4.1 :3D view of the proposed machine

4.1.3. Block making process sequence

Raw material loading (Figure 4.3), hopper door closing (Figure 4.4), first stage compression (Figure 4.5) and second stage compression (Figure 4.6) are the basic system process sequence of the proposed machine. The raw material loading to the hopper is done by manually or by using incorporated conveyor belt system with timers. After the loading is finished the hopper door is closed. While the door is come to the closing position the incorporated limit switch is operated. And then according to the above signal and the position signal of the second stage, the first stage of the compression is started. The first stage piston comes to the end position, the incorporated limit switch is operated and quickly stopped that first stage and the second stage is started. After the second stage reached to the compression pressure (blocking pressure) the incorporated the limit switch is activated and stop the second stage and return back to second stage cylinder up to initial position.

Normally the compactors requires the end door for generate the reactive force for block forming against the force applied from the hydraulic cylinder. Without using this type of door can generate the reactive force from the side walls of the compaction chamber. That means can move the side wall into the chamber by using incorporated bolts and nuts arrangements. The incorporated system illustrated figure is shown in Figure 4.2.

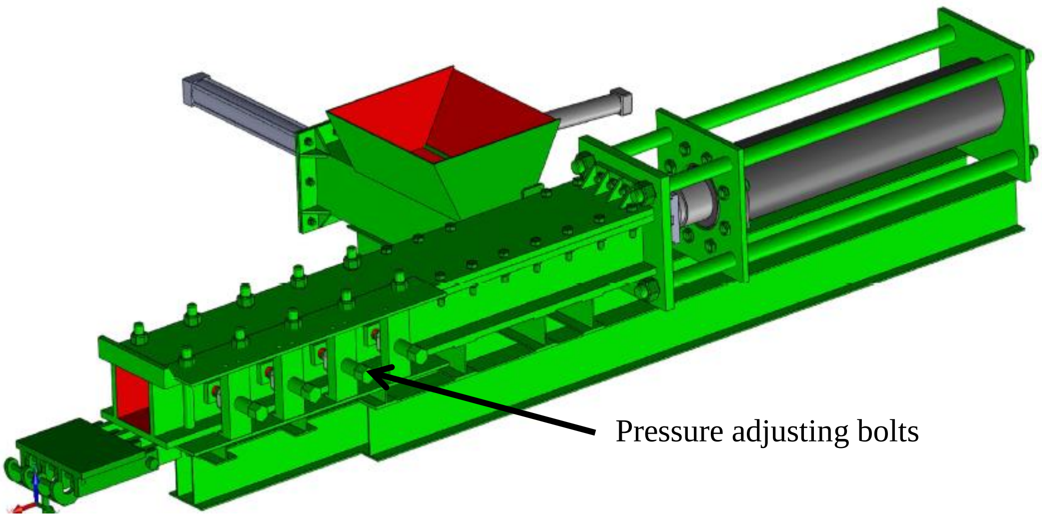


Figure 4.2: Illustrations of pressure adjusting system

From using the above technique it is required to stock some amount of blocks (15 blocks) in the end part of the compaction chamber. Otherwise the cylinder piston gets stuck in the narrowed area. So this system, the cylinder moves part of the stroke in the compaction chamber and other part only the blocks are moved. For this system the machine is tuned to reach the selected location which the required force is generated. If the force is not enough the side pressure adjuster required to adjust and synchronize the production process. Once put the raw material to the chamber the volume of this comes out from the compaction chamber as the block while the main compaction cylinder pushes. This type of system is defined as the door less compaction system.

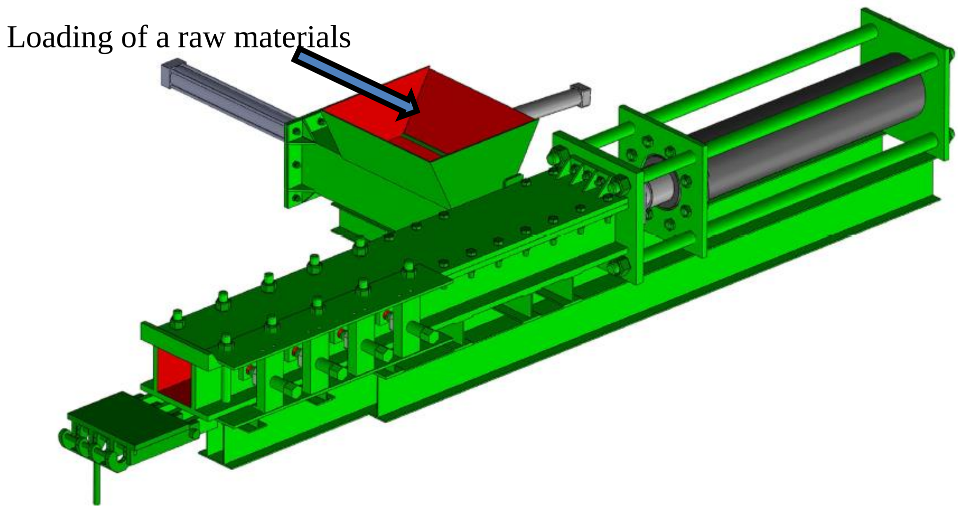


Figure 4.3 : Raw material is loading

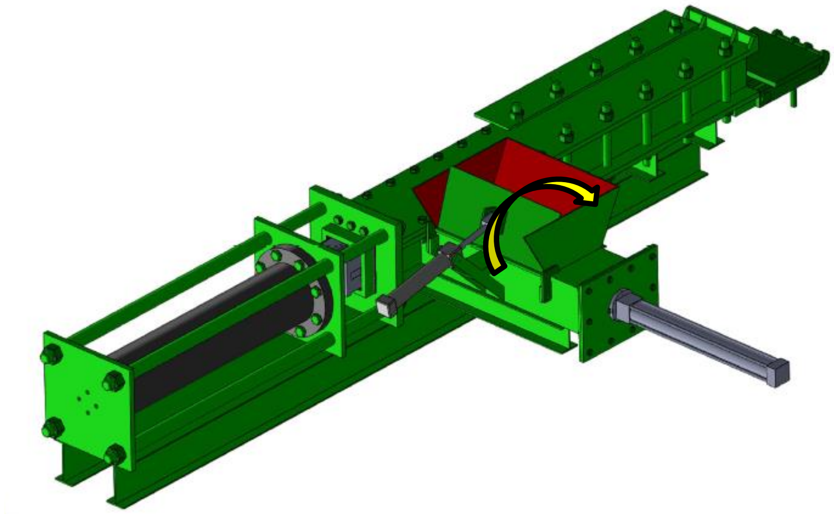


Figure 4.4 : Hopper door is closing

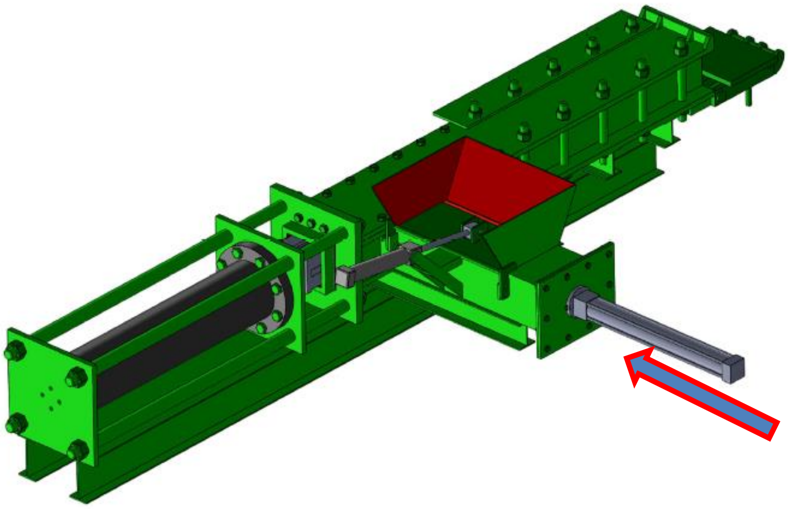


Figure 4.5 : First stage is in process

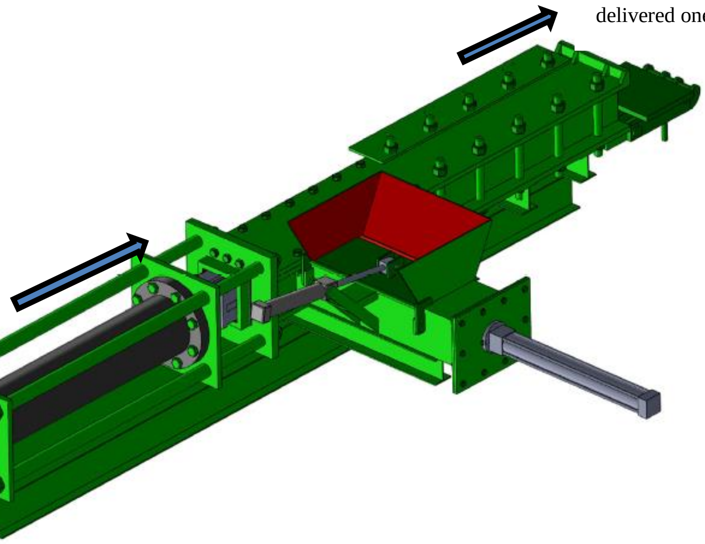


Figure 4.6 : Second stage in process

4.2. Designing of the hydraulic system

With using the related engineering design hand books [34] , the design calculations were completed and final technical drawings were finalized.

4.2.1. System design

Conclusions of the chapter 3, it was found that 20 MT applied load to 80 mm * 80 mm section square block is enough for making solid block. So based on these results calculations were performed.

Optimum maximum load for square block forming of the 80 mm × 80 mm, Cross section is 15Mt to20 MT

Applied surface pressure = (Applied load)/ (Cross section area of the block) --- (4.1)

$$= \frac{20000}{8.0 \times 8.0}\ kg/cm^2$$

$$= 312.5\ kg/cm^2$$

$$\approx 300\ kg/cm^2$$

Note: From the results of the experimental analysis it was shown that 15T to 20T load is sufficient. So designing this compactor it was used 300 kg/cm^2 for optimum surface pressure where it was around 80% of the pressure range).

Therefore, from equation 4.1, the applied surface pressure for block,

$$= 300\ kg/cm^2$$

Surface pressure for block forming is independent from the cross section of the block. And also from brainstorming sessions and the literature survey the optimum block cross section was square with 200 × 200 mm^2 size.

Therefore, required force for block forming from equation 4.1,

$$= 300 \times 20 \times 20\ kg$$

$$= 120{,}000 kg$$

$$= 120 MT$$

However, for design purposes, the required force for 200 × 200 mm^2 block is around 120 MT.

Optimum maximum pressure of commercially available hydraulic pumps is 300 kg/cm^2.

Therefore, relevant hydraulic cylinder diameter from equation 4.1 (it uses the cross section as the hydraulic cylinder piston cross section),

Relevant hydraulic cylinder radius $= \sqrt{\frac{(120\times10^3)}{300\times\pi}}$

$= 11.28cm$

Relevant hydraulic cylinder diameter $= 225.6\ mm$

According to the hydraulic systems manufactures, common hydraulics cylinders available are 225 mm and 200 mm diameters. So the system, most suitable cylinder diameter (d_1) is 225 mm, the ram diameter (d_2) is 160 mm and the stroke (L) is 1000 mm.

For actuating hopper door and first stage compression is selected 50 mm diameter and 63 mm diameter hydraulic cylinders accordingly. Maximum load applied for the system is calculated as follows according to the maximum pressure.

Maximum force applied to the machine from 50 mm diameter cylinder (F_2) from equation 4.2,

$$F_2 = 300\times\pi\times2.5^2/1000$$
$$= 5.8MT$$

Maximum force applied to the machine from 63 mm diameter cylinder (F_3) from equation 4.2,

$$F_3 = 300\times\pi\times3.1^2/1000$$
$$= 9MT$$

4.2.2. Calculations for finding hydraulic oil flow rate

Hydraulic oil flow rate calculations, following assumptions were considered; Hydraulic cylinder piston height is negligible, Time taken for material loading to hopper (t_1) is 10 s; and Front movement of main hydraulic cylinder uses regenerative system.

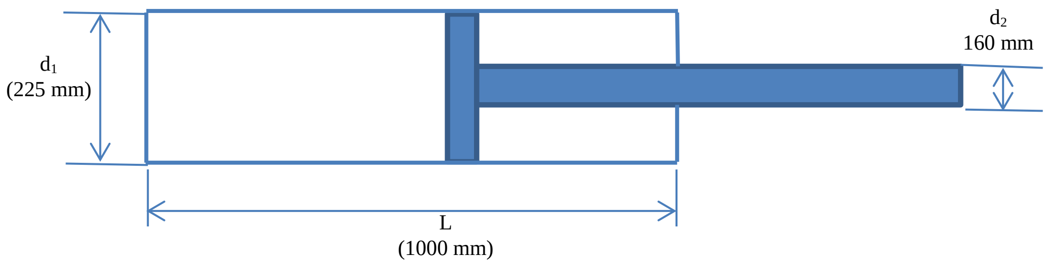


Figure 4.7 : Schematic diagram of a main hydraulic cylinder

Both oil accumulated in the front portion of the cylinder and the oil supply from the pump are used for forward movement of the cylinder which describe as the regeneration of the hydraulic system. Traditionally, the accumulated oil in the front portion is released to the oil reservoir while the cylinder moves forward.

The volume of oil inside the cylinders is shown in equation 4.2,

Volume = Area of the piston × Stroke ---(4.2)

The equation for finding the oil flow rate is shown in equation 4.3,

Flow rate= (Volume)/Time --(4.3)

From equation 4.2, the oil volume (V_1) required for front movement of cylinder with regeneration system is,

$V_1 = \{(d_1)^2-(d_1^2-d_2^2))\}\times L/4;$ [d_1=225mm, d_2 =160mm,L=1000mm]

$$=\left\{\pi\left(\frac{225}{2}\right)^2\times 1000-\pi\left[\left(\frac{225}{2}\right)^2-\left(\frac{160}{2}\right)^2\right]\times 1000\right\}\times 10^{-6}$$

$= 20.1l$

Oil volume (V_2) for reverse movement of cylinder from equation 4.2,

$V_2 = (d_1^2-d_2^2)\times L/4;$ [d_1=225mm, d_2 =160mm,L=1000mm]

$$=\left\{\pi\left[\left(\frac{225}{2}\right)^2-\left(\frac{160}{2}\right)^2\right]\times 1000\right\}\times 10^{-6}$$

$=19.6l$

Oil volume (V) for one complete cycle,

$V = (V_1+V_2)$

$= 39.7\ l$

Assume three cycles are performed in one minute (only main cylinder is in operation)

Therefore, required oil flow rate from equation 4.3,

$= (V\times3)\ l/min$

$= 119.1\ l/min$

Maintaining this oil flow rate, it is required to use very high power motor. So prevent that it uses double pump (high flow rate low pressure and low flow rate high pressure) techniques. That means when the system pressure is rise up, low pressure pump is cut-off. And also system running under low pressure the both pumps are supplied the oil to the system. So considering the commercially available pumps, it was found that 110 *l*/min low pressure pump and 25 *l*/min high pressure pump.

4.2.3. Calculation for motor power

Maximum pressure of the system $= 300\ kg/cm^2$

$P = 300\times9.81\times10^4$

$=29.4\times10^6\ N/m^2$

High pressure pump flow rate $V = 25\ l/min$

Power requirement (max) $= PV$

$= 29.4\times10^6\times25\times10^{-3}/60$

$= 12\ kW$

4.2.4. Hydraulic circuit diagram

Hydraulic system of this proposed machine was shown in Figure 4.8.This includes the three hydraulic double acting actuators, Directional valves for each actuators, Hydraulic double vane pump and oil reservoirs. Main actuator used pilot operated directional control solenoid valve and others used direct operated directional control solenoid valves.

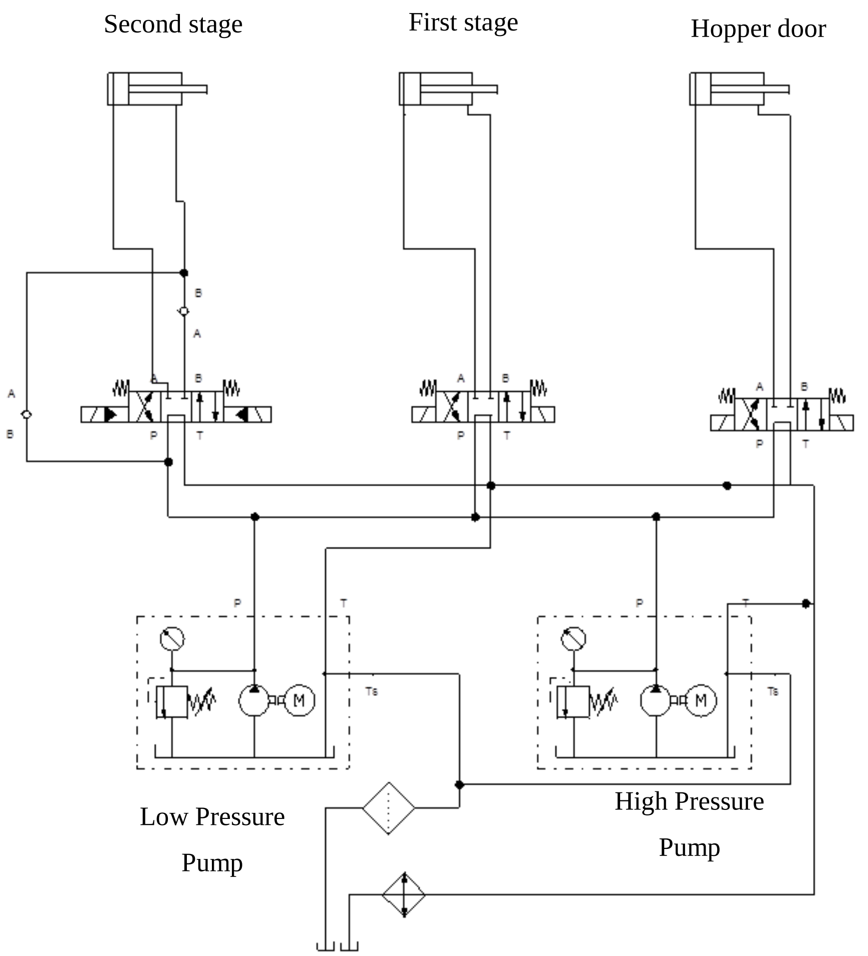


Figure 4.8 : **Hydraulic Circuit Diagram**

4.2.5. Calculations for production flow rate

According to the above experimental analysis (Chapter3.4),

Block height for 80 × 80 mm^2 cross section is 70 mm.

Volume of the compressed blocks and the weight are promotional in according to these systems.

Weight of experimental/Weight of actual=Volume of experimental/Volume of actual --(4.4)

$$\frac{0.2}{2} = \frac{80 \times 80 \times 70}{200 \times 200 \times h}$$

$$h = 112mm$$

So projected height of the compressed block is 112 mm. For calculation projected block height (*h*) is assumed as 120 mm.

Time taken only for front movement while the block is ejected (t_3) using high pressure pump (only compression) from equation 4.3,

Time (t_3) = Oil volume/oil flow rate

$= \{(d_1)^2-(d_1^2-d_2^2))\} \times (h/4)$/oil flow rate of small pump

$=\left\{\pi\left(\frac{225}{2}\right)^2 \times 120 - \pi\left[\left(\frac{225}{2}\right)^2 - \left(\frac{160}{2}\right)^2\right] \times 120\right\} \times 10^{-6} \times 1/25$ min

= 5.8s

~ 6s

According to the selected pump,

Time taken for movement (full cycle) of main cylinder (t_4) from equation 4.3,

t_4 = (39.7/135) min

= 17.6 s

~ 18s

In hydraulic power pack it was used low flow rate pump for operate door and the first stage. Because the high flow pump was not used in practically.

Time taken for door closed operation (t_5) from equation 4.3, (50 mm diameter, 28mm diameter shaft 400 mm stroke cylinder was used with 25 *l*/min flow rate.)

$$t_5 = \pi \times 25^2 \times 400 \times 10^{-6} \times \frac{1}{25}\, min$$

$=2\ s$

Time taken for door open (t_6) from equation 4.3,

$$t_6 = \pi \times (25^2 - 14^2) \times 400 \times 10^{-6} \times \frac{1}{25}\, min$$

= 1.29 s

~ 1.3 s

Time taken for first stage front movement (t_7) from equation 4.3, (63 mm diameter 900 mm stroke cylinder was used with 25 *l*/min flow rate.)

$$t_7 = \pi \times 31.5^2 \times 900 \times 10^{-6} \times \frac{1}{25}\, min$$

=6.7 s

Time taken for first stage return movement (t_8) from equation 3,

$$t_8 = \pi \times (31.5^2 - 14^2) \times 900 \times 10^{-6} \times \frac{1}{25}\, min$$

=5.4 s

Calculating the cycle time it is required to add the cylinders actuating and retraction times and the time for loading and the compaction block ejecting time. But in the process sequence the main cylinder pass the first stage to second stage input chute, the door opening and the first stage returning is done before the main cylinder comes to the returned position. So cycle time calculation can reduce the above times. Assume material loading time (t_1) is 10s.

So cycle time (T) for compressing one block

$$T = (t_1 + t_3 + t_4 + t_5 + t_7)$$
$$= \{(10+6+18+2+6.7\} \text{ s}$$
$$= 42.7\text{s}$$

Proposed production rate (R_1),

$$R_1 = 1/T$$
$$= 60 \times 60/42.7$$
$$= 84 \text{ blocks/h}$$

Actual scenario the main cylinder was not moving up to 1000 mm. Normally its moves between 50% to 100% stroke where the machine uses a door less system. Other cylinders move total specified strokes while in operation.

If the main cylinder moves up to 50% of stroke,

The required time for one movement of main

Cylinder (t_4'), $=18 \times 0.5$

$=10.8$ s

Total cycle time (T'), $= \{(10+6+9+2+6.7\}$ s

$= 33.7$s

Proposed production rate (R_2), $= 60 \times 60/33.7$

$= 106$ blocks/h

From above calculations the machine production rate can vary in between 84 blocks/h to106 blocks/h.

4.3. Designing the electrical system

The process sequence of this machine is quit complex and it is required more manual labour. So avoiding above it is proposed to operate with semi-automatic operation. For operation of this sequence it can be used separate relays and timers' circuit or Programmable Logic Controller (PLC) for control panel. Reducing the complexity of the control panel it was used PLC. The ladder diagram required to program the PLC is attached in annexes. The inputs of the PLC are used six limit switches and manual operation buttons, pressure cutoff switch and other selector switches. The out puts of the PLC are used relays, lights, sirens and motor contactors. The control panel used 24V operating voltage and it includes the relays for interference with PLC to directional controls. The motor control used star/delta motor starter with three contactors and timer. This panel used manual operation buttons and auto operation buttons and selector switches.

The control panel includes the several safety features. Over pressure cutoff system, Critical operation of first stage compression limit cutoff used two limit switches for increasing reliability were the main safety features and also it was used light pole and siren for better identification of the machine operation.

4.4. Designing of the compaction machine

4.4.1. Introduction

Designing of the compaction machine it is required to find the basic sizes of the machine which includes the hopper size, first stage input chute size, second stage input chute size and the compaction ratios.

4.4.2. Size determination of the input chute

This hopper is attached to the first stage and the above combination is attached to the frame of the second stage where the height (h) of the first stage is same as the compressed blocked height. The top part (funnel shape) is used only for easiness of the raw material loading.

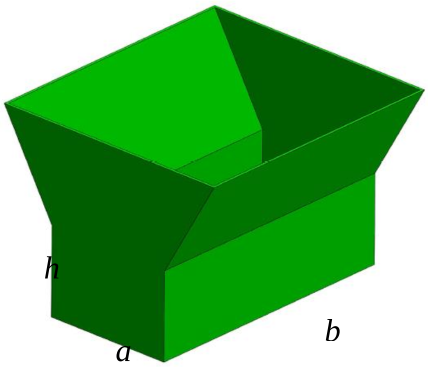


Figure 4.9 : **Schematic diagram of the hopper**

The proposed block weight is 2kg and it has a free volume (V_1) of 50 *l* (Bulk volume of the raw materials is 25*l*/kg). So this volume of material should put into the hopper without any compression

Therefore, h = 200 mm

$$Volume\ of\ the\ hopper = width \times Length \times Height \quad \text{-------------------}\mathbf{(4.5)}$$

$$= a \times b \times h$$

$$Volume\ of\ the\ hopper \geq free\ volume\ of\ the\ raw\ material\ (V_1) \quad \text{--------------}\mathbf{(4.6)}$$

$$a \times b \times h \geq 50 \times 10^{-3}$$

$$a \times b \geq 0.25\ m^2$$

From equation 4.6 and the design limitations, *b* can be assumed as 300 mm. Therefore, the best *a* value is 900 mm.

4.4.3. Calculations for compression ratios

The calculations of the compaction ratios of each stage are as follows,

Volume of a raw material feed (V_1), (Bulk volume of the raw material are 25*l*/kg)

$$V_1 = 0.05\ m^3$$

Inlet volume of the second stage (V_2) height *(h)* is 200 mm, width *(a)* is 300 mm and depth *(c)* is 200 mm,

$$V_2 = a \times c \times h$$

$$= 0.3 \times 0.2 \times 0.2$$

$$= 0.012\ m3$$

Therefore, compression ratio of the first stage from V_1 and V_2,

$$= V_1 / V_2$$

$$= 4.5:1$$

Final projected block size is 200 mm * 200 mm * 120 mm. So,

Volume of a final block (V_3)= $0.2 \times 0.2 \times 0.12\ m^3$

$$= 0.0048\ m^3$$

Volume of inlet of a second stage (V_2)

$$V_2 = 0.012\ m^3$$

So second stage compression ratio from V_2 and V_3,

$$= V_2 / V_3$$

$$= 2.5:1$$

4.4.4. Calculations for main frame

Chapter 2 and 3 analysis was found that the force required for forming blocks are required 120MT load. So the main structure should withstand 120 MT force.

For designing the frame of the compaction machine following assumptions are considered. Mild steel (1090) is suitable for the frame and its yield strength (Y) is 240 MPa. Considering the quality of the available materials in the market this was considered the 50% of yield strength is the strength value available in raw materials and the factor of safety (SF) was selected as 2.

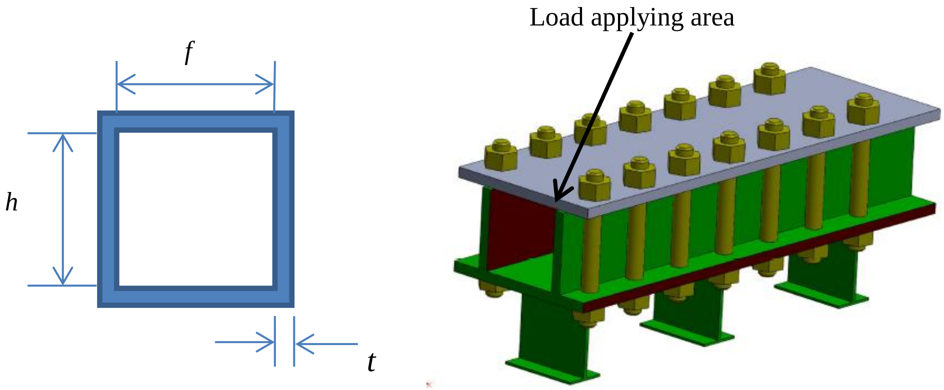


Figure 4.10: Cross section of the main frame

According to stress calculations the strength of the frame was calculated. The maximum load is applied in second stage to first stage joining area. Area (*A*) is the area where the load applied and *F* is 120 MT where it is designed load.

$$\textit{Yield strength } (Y) \geq \textit{Allowable strength} \times \textit{Safety factor} \quad \text{----------------}(4.7)$$

$$Y \times 0.5 \geq F \times SF/A$$

$$A = 2ht + 2(2t + f)t \quad ;[\ h = 200\text{mm},\ f = 200\text{mm}]$$

$$240 \times 10^{6} \times 0.5 \geq \frac{120 \times 10^{3} \times 9.81 \times 2}{4t \times (0.2 + t)}$$

$$t \geq 22.08 \times 10^{-3} m$$

But considering the fatigue in real situations of the materials and the past experience it was designed as 25 mm thickness is optimal.

4.4.5. Calculations for the first-stage frame

For designing the frame of the first stage following assumptions are considered. Mild steel (1090) is suitable for the frame and its yield strength (Y) is 240 MPa. Considering the quality of the available materials in the market this is considered the 50% of yield strength is the strength value available in raw materials and the factor of safety (SF) is selected as 2.

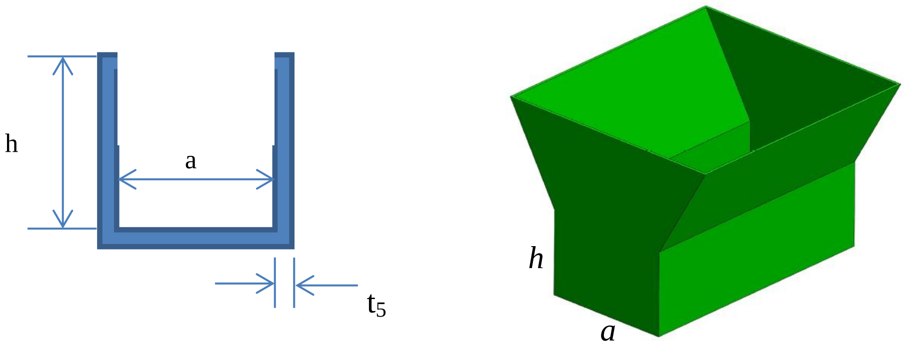


Figure 4.11 : Cross section of the first stage frame

According to stress calculations the strength of the frame was calculated. The maximum load is applied in second stage to first stage joining area. Area (*A*) is the area where the load applied and *F* is 9 MT where it is found in the chapter 4.2.1.

$$\text{Yield strength } (Y) \geq \text{Allowable strength } \times \text{Safety factor} \quad \text{----------------}(4.8)$$

$$Y \times 0.5 \geq F \times SF/A$$

$$A = 2ht_5 + (2t_5 + a)t_5 \;;[\, h = 200\text{mm},\ a = 300\text{mm}]$$

$$240 \times 10^6 \times 0.5 \geq \frac{9 \times 10^3 \times 9.81 \times 2}{t_5 \times (0.7 + 2t_5)}$$

$$t \geq 2.08 \times 10^{-3} m$$

But considering the fatigue in real situations of the materials, the past experience and the fabrication it is designed 10mm thickness as the optimal.

4.4.6. Calculations for main cylinder fixings

According to the main cylinder standard mounting arrangements, the front flange arrangement is the suitable for this type of hydraulic press. The front flange diameter of the main cylinder is smaller than the machine frame and this generate difficult situation to bolting. So connecting this cylinder to the frame it is used four tighten bolts which attached to the square plate according to the Figure 4.12.The one side of the one plate is welded to the frame.

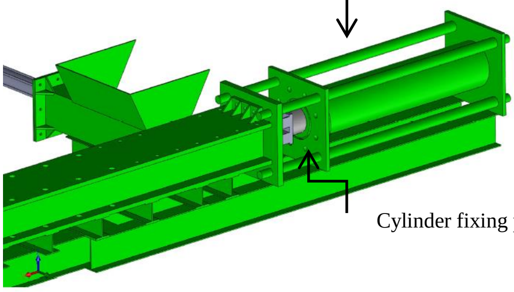


Figure 4.12 : Main cylinder fixings

Tensile load is applied to the cylinder fixing bolts. Factor of safety is 2 and the bright mild steel tensile stress is 840MPa with using the design limit of 50% are the assumptions. According to the above assumptions the fixing bolts size are calculated from using equation 4.7,

$$Y \times 0.5 \geq F \times SF/A$$

$$A = 4 \times \pi r^2$$

$$840 \times 10^6 \times 0.5 \geq \frac{120 \times 10^3 \times 9.81 \times 2}{4\pi r^2}$$

$$r \geq 0.021\ m$$

$$r \geq 21\ mm$$

So considering the above value, the minimum diameter of the bolts is selected as 48 mm. Main frame fixing plate is fixed using the welding. So strength of the welding was designed to withstand 120 MT force.

4.4.7. Calculations for second-stage piston

The piston of the main cylinder (second stage) also required to withstand the maximum load of 120MT.The piston plate is subjected to shear failure after the bending.

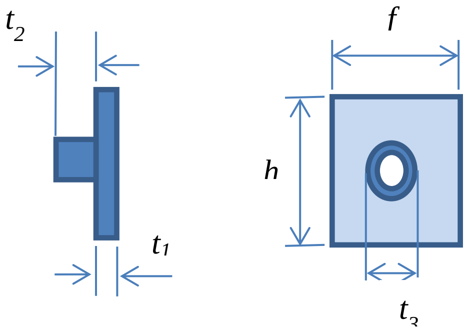


Figure 4.13 : Front and side elevation of the second stage cylinder piston

While in compression, shearing was happened due to the 120 MT to the piston and according to the assumptions (factor of safety is 2 and shear stress of the mild steel is 240 MPa) and from equation 4.7, the thickness of the piston plate was calculated. For selecting the shearing area, the cylinder rod diameter (r=80 mm) was considered and this is the standard rod diameter for selected hydraulic cylinder.

$$Y \times 0.5 \geq F \times SF/A \text{ -------------------------- } (4.7)$$

$$A = 2\pi \times r \times t_1$$

$$240 \times 10^6 \geq \frac{120 \times 10^3 \times 9.81 \times 2}{2\pi \times r \times t_1}$$

$$t_1 \geq 19.51 \times 10^{-3} m$$

The real situation and the past experience it is required to get the more thicker considering the failure of fatigue. So it is selected 25 mm as the thickness of the piston. Also preventing the bending it is required do the reinforcement.

The height of the piston boss (t_2) depended on specifications of the cylinder ram and its size is 75 mm. Thickness of the boss (t_3) is depending on the t_2 and the size of the piston. So the maximum thickness of the boss is selected as 20mm.

4.4.8. Developed compaction machine

According to the results (chapter 3.5) the compaction machine was designed. The 3D view of the designed machine was shown in Figure 4.14. This includes the material loading hopper, first stage compaction chamber, and Second stage compaction chamber. And also power pack of the hydraulic system is attached separately to the machine with flexible hydraulic hoses.

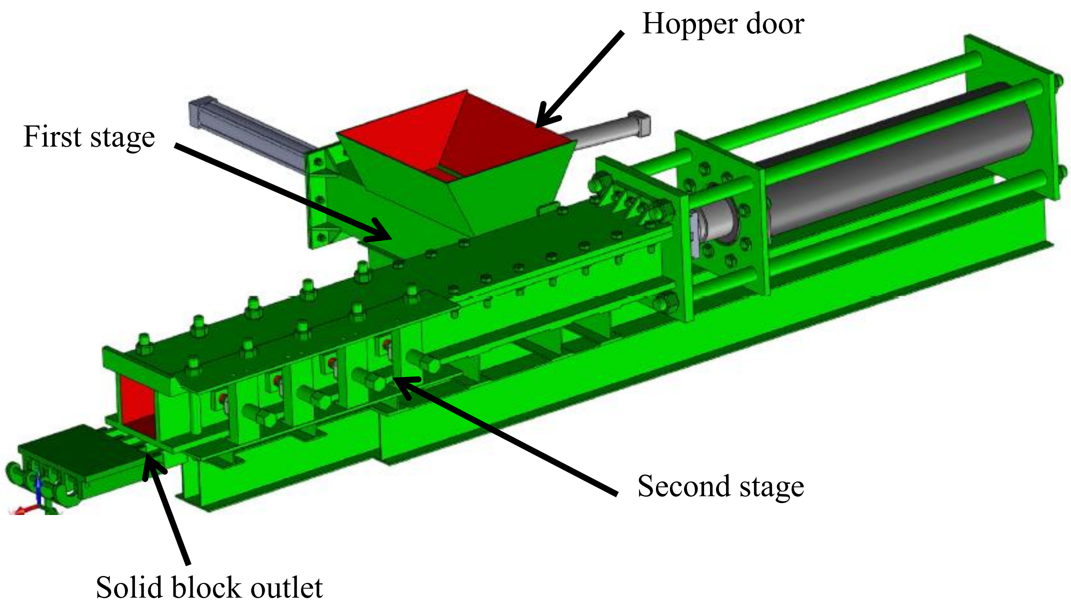


Figure 4.14 : 3D view of the compaction machine

4.5. Result verification

Comprising all the details found during the literature survey (Chapter 2) and the experimental analysis (chapter 3), the compaction machine was designed. After completing the detail design the machine was fabricated in the department of Agricultural Engineering and post-harvest technology in National Engineering Research and Development Centre. Once the machine was fabricated, in-house testing was done with the minor modifications. After completing the machine it was send to the Pelwatte dairy, Buttala for conduct the field testing (Figure 4.15 : The machine was in field testing) with correct recipes which was used for castles in NLDB Farms.

Figure 4.15 : The machine was in field testing

The field testing were conducted in three months with the three persons ,two for preparing feed mixture and other for raw material loading to the machine and the following results were obtained in each above recipes and shown in Table 4.1. The production capacity, dimensions of the final block just after the block forming and one day after were the tabulated results. Measuring of the block dimensions the cross section area was remaining unchanged. Only the height was measured randomly during the field testing.

4.6. Results from field testing

Table 4.1: Actual results of the fabricated machine including the final block size and the production

Machine working time/(h)	No of blocks produce	Block height/(mm)					
		Sample 1		Sample 2		Sample 3	
		Just after	After one day	Just after	After one day	Just after	After one day
8	880	100	115	100	110	100	120
7	700	95	100	100	105	100	105
4	430	100	110	100	110	100	110
5	510	105	115	105	120	100	110
8	850	95	100	95	100	90	100
8	850	100	115	110	120	100	115
7	600	100	115	100	120	95	115
8	750	100	120	95	110	90	105
3	330	90	105	90	100	90	110
6.5	680	90	100	95	105	90	100

During the field testing it was observed the block forming pressure of the compaction machine. It was shown as around 200kg/cm^2.According to the observed pressure the block forming load from equation 4.1,

$$= 200 \times \pi \times 11.25^2$$

$$= 79.52MT$$

$$= 80MT$$

Production rate is normally depended on the type of the raw materials, moisture content of the raw materials, applied load for block making. Behalf of that the door less compaction system also depended the block size and also this is not included the raw material mixing time for the production.

From the above results the average production was calculated.

The average production rate =102.6 block/h

~ 102 block/h

Actually in practical situations it was varied in between 85 block/h to 110block/h.

From the above tabulated results it was found the average block heights.

Average block height after one day = 109.5 mm

~110 mm

Average block height just after = 97.34 mm

~ 97 mm

4.7. Discussion

The compaction machine was designed according to the found results from previous chapters (Chapter 2 & Chapter 3).According to the design, the production capacity is within 84 blocks/h to 106 blocks/h and the size is 200mm*200mm*120mm.After the design was completed the machine was fabricated and hereafter field testing’s performed in Pelwatte dairy industries. In the field testing the machine was shown 85 block/h to 110block/h of varied production capacity. The height of the block just after the compaction is varied in between 90mm to 100mm and after the one hour it is varied in between 100mm to 120mm. Finally the machine was obtained the average production capacity of 102block/h and average height of 110mm during the field testing of the machine.

The actual production capacity and the block height are slightly varied to the designed data. Because it is happen in the door less compaction system. Normally every time 15 blocks are stocked in the main chamber of the machine. So the each stocked blocks are applied 15 times of maximum load (compaction load).In the experimental analysis only one time loading to the block is applied. Due to the more applied loads in several times (repeat loads) the designed block height and the actual height is varied. And also the block formed in lower pressure (lower loads, 80MT) due the repeat loads and the storage. So door less system obtained the more advantages than the door system to compaction machine.

In design calculation assume the raw material loading time is 10s. But in real situation the time of main cylinder pass the input chute and return back is larger than the return back of first stage and the door opening. So after fabrication the raw material loading time is reduced up to 5s.Then the design production capacity is in between 85blocks/h to125 blocks/h. According to the above the actual production is within the design range.

4.8. Conclusion

Found results from the chapter 2 and chapter 3, the suitable compaction machine was designed. Then the machine was fabricated and did the field testing. After the field testing results were observed. Hence found the observed results and the design parameters were the same. Finally the machine was obtained the average production capacity of 102block/h and average height of 110mm during the field testing of the machine. In future this machine will require to fixing the automatic material mixer and conveyor to load the raw materials to the compaction machine hopper.

4.9. Chapter summary

This chapter discussed the detail design, fabrication and field testing of the solid feed block making machine. From the field testing results proved the parameters for forming blocks discussed in above chapters (Chapter 2 and 3).

5 DISCUSSION

Brain storming session (Chapter 3.5.1) conducted at NERD Centre was found that the requirements of the solid feed block for cattle farmers while in the food scarcity periods. Furthermore, it was found that land areas were reducing due to land fragmentations of large areas of cattle farming. Therefore, it was clearly showed that, a great requirement of portable solid nutritious feed blocks for these farms. Scientists who are working with dairy field also proved the above requirements too.

Considering the feed blocks available in the world it was a major task for finding the suitable block for Sri Lankan context. According to the expert's knowledge and the simple analytical method (Chapter 3.5.2) it was found that the most suitable feed block for Sri Lankan farmers are solid fodder block which was included the hay and the other nutrients.

Four different recipes were found with different moisture levels through experimental analysis (Chapter 3.5.4). It is also found the suitable shape of the mould to form solid feed block in optimal conditions. Lower moisture level less than 20% were the optimum moisture level for forming the solid blocks. All the recipes used for cattle were included the same raw materials with different percentages. According to the above analysis, it was found that there was no huge variation of parameters for blocks forming. The required surface pressure for forming solid feed block was 234 kg/cm^2 to 312 kg/cm^2 and this pressure range shown that the block forming parameters were same according to the experimental analysis results. Fabrication of the square block forming machine was got huge advantages than the circular shape. Because square shape block forming can easily make the machine with less operation of the door. That means this system can easily to convert into the continuous process. The production cost is also lower than circular blocks. Packaging of the blocks can be done with polythene easily.

Finally, the industrial compaction machine for solid feed block was designed and fabricated with above considered factors. From the design it was found 2kg weight blocks with the production rate of 84 blocks/h to 106 blocks/h and the size is 200mm*200mm*120mm. After the fabrication was finished the machine was send to the Pelwatte dairy, Buttala for field testing. From the field testing, the machine was shown 85 block/h to 110block/h of varied production capacity. The height of the block just after the compaction is varied in between 90mm to 100mm and after the one hour it is varied in between 100mm to 120mm. Finally the machine was obtained the average production capacity of 102block/h and average height of 110mm during the field testing of the machine.

The actual production capacity and the block height are slightly varied to the designed data. Because it is happen in the door less compaction system. Normally every time 15 blocks are stocked in the main chamber of the machine. So the each stocked blocks are applied 15 times of maximum load (compaction load).In the experimental analysis only one time loading to the block is applied. Due to the more applied loads in several times the designed block height and the actual height is varied. While in the block forming, the maximum pressure reach in the system was around 200kg/cm^2. The designed pressure was 300 kg/cm^2.So value was also varying due to the block storage in the compaction chamber. So storage and the door less system of the compaction machine had a huge advantage compared to the main chamber door operated system.

In design calculation assume the raw material loading time is 10s. But in real situation the time of main cylinder pass the input chute and return back is larger than the return back of first stage and the door opening. So after fabrication the raw material loading time is reduced up to 5s.Then the design production capacity is in between 85blocks/h to125 blocks/h. According to the above the actual production is within the design range. Comparing the design details and the analytical method the proposed block height was also same as the actual block made by the developed machine.

6 CONCLUSION & RECOMMENDATIONS

The literature survey was illustrated the requirements of feed blocks. Therefore, it was found more viable type of block, its specifications and the suitable rations of the mixture. According to the experiment and the trials, it was found the most suitable compaction pressure required for foaming the blocks (Surface Pressure 234 kg/cm^2 to 312 kg/cm^2). Therefore, considering above all factors, the two stage compaction machine was successfully designed, developed and fabricated. The design specifications and all predictions from the design stage of the feed block machine were well fitted with the actual values. The actual and expected production capacities were 85 - 110 Blocks/h and 84 - 106 Blocks/h , the average actual and expected production capacities were 102 blocks/h and 95blocks/h and actual and expected size of the block the cross section were 110 mm and 112 mm respectively. However, actual height of the block was obtained lower value due to the machine door less system incorporated in the compaction machine.

Furthermore, the machine was developed according to the requirements of the customer and in future it will be expanded up to the automatic hay cutting, automatic raw material mixing and automatic loading to the compaction machine etc. Therefore, completing the whole set of feed block making plant can obtain the higher production and ultimately it will increase the milk production yield in Sri Lanka. Finally, it can reduce the importation of milk powder to Sri Lanka which was the requirement of government in last few years.

7 REFERENCES

[1] H. Abegunawardana, D.Rathnayake and W.M.A.P.Jayathilaka, "characteristics of cattle farming systems in sri lanka," *National council of Sri Lanka,* vol. 1, pp. 25-38, 1997.

[2] Ministry Of Agriculture And Livestock, "Sri Lanka live stock Statistics," Department of Agriculture, Peradeniya, 2012.

[3] Department of Census and Statistics, Central Bank Annual Report, 2012.

[4] A.N.F.Perera, J. S.Siriwardana and S.Premarathne, "Fibrous Crop Residues as a Ruminant," *Handbook of veterinarians,* pp. 24-34, 1999.

[5] P.McDonald, R.A.Edwards, J.F.D.Greenhalgh and C.A.Morgan, Animal Nutrition, India: Tan prints pvt Ltd, 1988, pp. 335-426.

[6] M.N.M.Ibrahim and T.N.Jayathileka, "Livestock Production under coconut plantations in Sri Lanka,Cattle and buffalo production systems," *Asian australian journal of Animal science,* vol. 13, pp. 60-67, 2000.

[7] S.Ranawana, "Dairy industry in Sri Lanka," in *Research Department of people's bank head office,* colombo, 2008.

[8] S.C.Somasiri, S.Premarathne, H.A.Abeysoma, C.M.B.Dematawewa and J.H.M.N.Satsara, "Effect of Gliricidia Leaf Meal Blocks on Intake," *Live Weight Grain and Milk Yield of Dairy Cows,* vol. 22, pp. 76-83, 2010.

[9] "Sri Lanka live stock Statistics," Department of Agriculture and Livestock, Peradeniya, 2006.

[10] B. Perera and M.C.N.Jayasooriya, "The Dairy industry in Sri Lanka:Current staus and future directions for a greater role in national development," *National Science Foundation,* vol. 36, pp. 115-126, 2008.

[11] S.premarathne and M.C.N.Jayasooriya, "Straw and fodder base supplementation for buffaloes,Proceeding of changing role of the buffoloes in the millennium in asia.," *National Science foundation,Sri lanka,* pp. 197-207, 2006.

[12] S.Premarathne, G.G.C.Premalal and V.P.Jayawardena, "Sustanable management of grassland resources for ruminant live stock production in Sri Lanka," *Tropical agricultural research and extension,* vol. 6, pp. 60-65, 2006.

[13] M.N.M.Ibrahim, Dairy cattle production, Peradeniya: Printing Unit,Faculty of Agriculture,Unversity of Peradeniya, 2000.

[14] B.M.A.O.Perera, H.Abegunawardena, W.G.Vale and C.Chantalakhana, "Improving the husbandry of animals kept by poor people in developing countries," *Livestock and welth Creation,* pp. 451-471, 2005.

[15] S. K.Ranjhan, "Proceeding – Utilization of Agro-industrial by-products as Livestock Feed," *Modern approaches to feed evaluation and their application in India. ,* no. New Delhi, 1993.

[16] NRC, " Nutrient Requirement of dairy cattle. 6th Revised Edition," National Academy Press, Washington, DC, 1989.

[17] A. R. C. (ARC), "The Nutrient Requirement of Ruminant Livestock," Commonwealth Agricultural Bureau, London, 1980.

[18] C.A.Moran, "Nutritional requirements of dairy cattle," *Applied animal nutrition,* no. 2, pp. 100-107, 2005.

[19] D.N.Verma, "Animal Nutrition," New Delhi, Kalyani Publishers, 1994, pp. 243-307.

[20] K.Samarasinghe, "Feed and Feed formulation for poultry in Sri Lanka," Peradeniya, Department of animal science,Faculty of Agriculture, 2007, pp. 73-79.

[21] C.A.Gopalakrishnan and G.M.M.Lal, "Livestock and poultry enterprises for rural development," New Delhi, Vikas publishing house, 1985, pp. 90-185.

[22] N. R. Council, " Nutrient Requirement of dairy cattle, 7th Revised Edition, Subcommittee on Dairy Cattle Nutrition Committee on Animal Nutrition Board on Agriculture and Natural Resources," 2000.

[23] 2015. [Online]. Available: http://www.fao.org/docrep/015/i2728e/i2728e00.pdf.

[24] K.C.Das, N.Haque and C.Rajkhowa, "Tree leaves and forest grasses based feed block for Mithun in North Eastern region of India," *Proceedings of the national symposium on fodder block technology,* no. ILDEX India–2009, New Delhi, p. 80–83, 2009.

[25] K.K.Singhal, "Scope for sugarcane bagasse based complete feed for ruminants," *Proceedings of the national symposium on fodder block technology,* no. ILDEX India–2009, New Delhi., pp. 93-98, 2009.

[26] A.K.Samanta, K.K.Singh, M.M.Das, S.B.Maity and S. Kundu, " 2003. Effect of complete feed block on nutrient utilization and rumen fermentation in barbari goats," *Small Ruminant Research,* no. 48, p. 95–102, 2003.

[27] T.K.Walli, " Densified TMR – A newer nutrient delivery system for feeding dairy animals in tropics," *XXXVI dairy industry conference,* no. BHU, Varanasi, India, p. 74–79, 2008 a,2009b,2010,2011.

[28] M.R.Garg and B.M.Bhanderi, "Enhancing livestock productivity through balanced feeding," *In S.S. Kundu, C. Dutt, V. Mani & A. Kumar.Proceedings of the 14th Biennial Conference,* no. Animal Nutritional Society of India, Pantnagar University of Agricul, p. 11–21, 2011.

[29] 2015. [Online]. Available: http://www.new-ag.info/en/focus/focusItem.

[30] [Online]. Available: http://www.agricultureinformation.com/postings/win-win-solution.

[31] R.Marchen, "Blocks and cub supplementation for Grazing Beef Cattle," *Texas cooperative extension,* 2005.

[32] N. R. C. (NRC), "Feeding tables," 2001.

[33] K. Kulathunga, "Preparation of cattle feed blocks using Agro waste," 2014.

[34] Joseph E.Shigley, Charles R. Mischke, Standard handbook of machine design, New York: McGraw-Hill,USA, 1996.

ANNEXES

Annex 01: Specifications of the hydraulic system and the controlling method

Main hydraulic cylinder (second stage)

- Double acting hydraulic cylinder with front flange mounted 224 mm (9in) diameter 1000 mm stroke
- Maximum pressure applicable: 300 kg/cm^2
- Ram diameter : 160 mm

First stage hydraulic cylinder

- Double acting hydraulic cylinder with front flange mounted 63 mm (2.5in) diameter 900 mm stroke
- Maximum pressure applicable: 250 kg/cm^2
- Hopper door operating hydraulic cylinder

  Double acting hydraulic cylinder with front flange mounted 50 mm (2in) diameter 400 mm stroke
- Maximum pressure applicable: 250 kg/cm^2

Hydraulic pump (Vane type)

- Volume flow rate low pressure :110 l/min
- Volume flow rate high pressure: 10 l/min
- Maximum pressure : 250 kg/cm^2

Hydraulic oil

- Hydraulic oil (HD 68) quantity :200l

Motor

- Three phase 15 hp induction motor, 415 V, 50 Hz

Hydraulic controllers

- 02 Nos of 4/3 way solenoid valves with manifold block, oil flow rate : 80 l/min (Port size ¼” Dia, 1/2” hydraulic hoses)
  - 01 Nos of 4/3 way solenoid valves with manifold block, oil flow rate : 300

l/min (Port size ¾" Dia,1 ¼" hydraulic hoses) with regeneration for main cylinder

Other hydraulic accessories

- Pressure relief valve, max pressure 300 kg/cm^2
- Electric pressure cutoff valve fixed to the main cylinder front moment
- Oil reservoir tank with capacity of 200l, with suction filter, oil filter, level gauge
- 150 l/min capacity water cooling type oil cooler.

Equipment of Electrical control panel

- Programmable logic controllers with 10 nos relay outputs, 10 no of digital inputs with 230 V operating voltage
- Metal enclosures, Electro Zinc coated sheet steel 2 mm thick with powder coated beige in textures finished, Hinged door & rubber gasket, ABC Key lock, Grand plate, Mounting plate, IP 54, IEC 529 standards, size 400 mm * 600 mm * 200 mm
- 06 Nos Goose neck type electric limit switches

Annex 02: Ladder diagram for PLC programming

Notations

Inputs

Input	**Definition**
X0	Cycle start
X1	Initial position of door (door open)
X2	closed position of door (door closed)
X3	Initial position of first stage
X4	Pressed position of first stage
X5	Initial position of second stage
X6	Pressed position of second stage
X7	Manual door close
X10	Manual first stage compression
X11	Manual second stage compression
X12	Manual second stage return
X13	Manual door open

X14	Manual first stage return
X15	Auto mode
X16	Pressure cutoff switch
X17	Preset

Outputs

Output	**Definition**
Y1	Door open
Y2	Door close
Y3	First stage return
Y4	First stage compression
Y5	Second stage return
Y6	Second stage compression
Y7	Error indicator (Buzzer+ red light)
Y10	Door closed alarm (bell)
Y11	High pressure check valve
Y12	Low pressure check valve
Y14	Material Loading (yellow light)
Y15	Auto mode indicator (green)

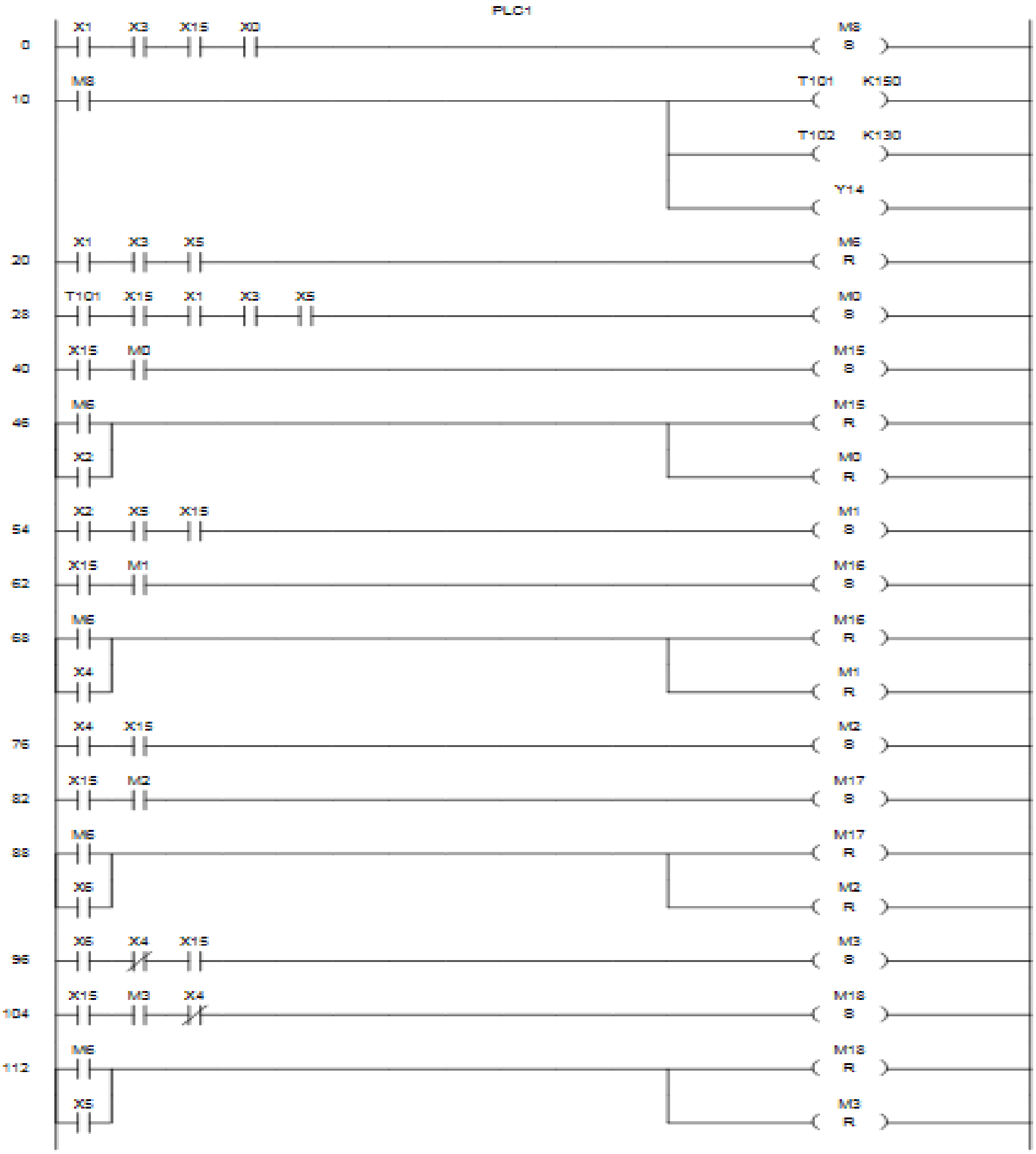
Memory

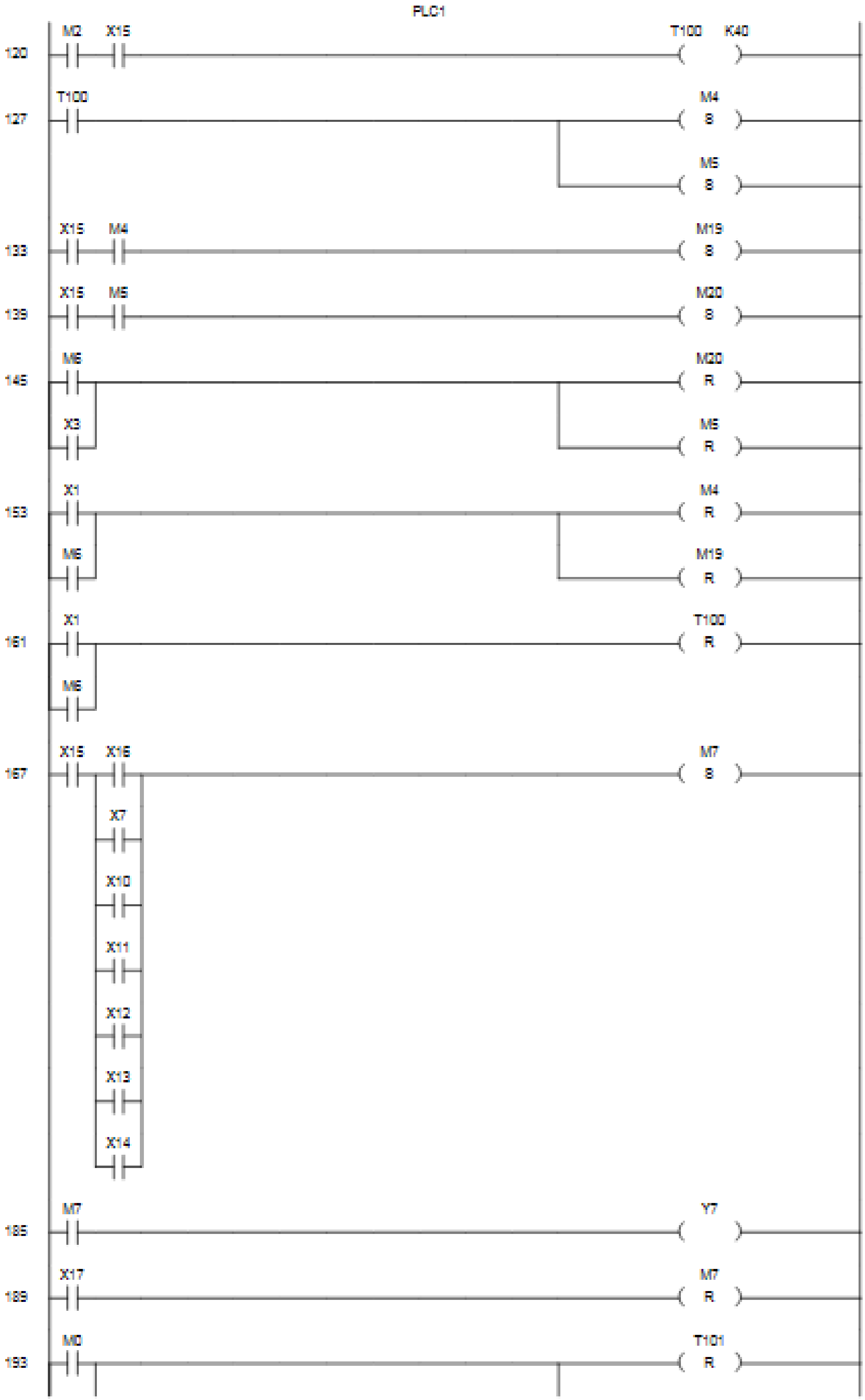
Memory	**Definition**
M0	Cycle start
M1	First stage compression
M2	Second stage compression
M3	Second stage return
M4	Door open
M5	First stage return
M6	Preset
M7	Error indicator
M8	Yellow light on
M15	Door close valve operation
M16	First stage compression valve

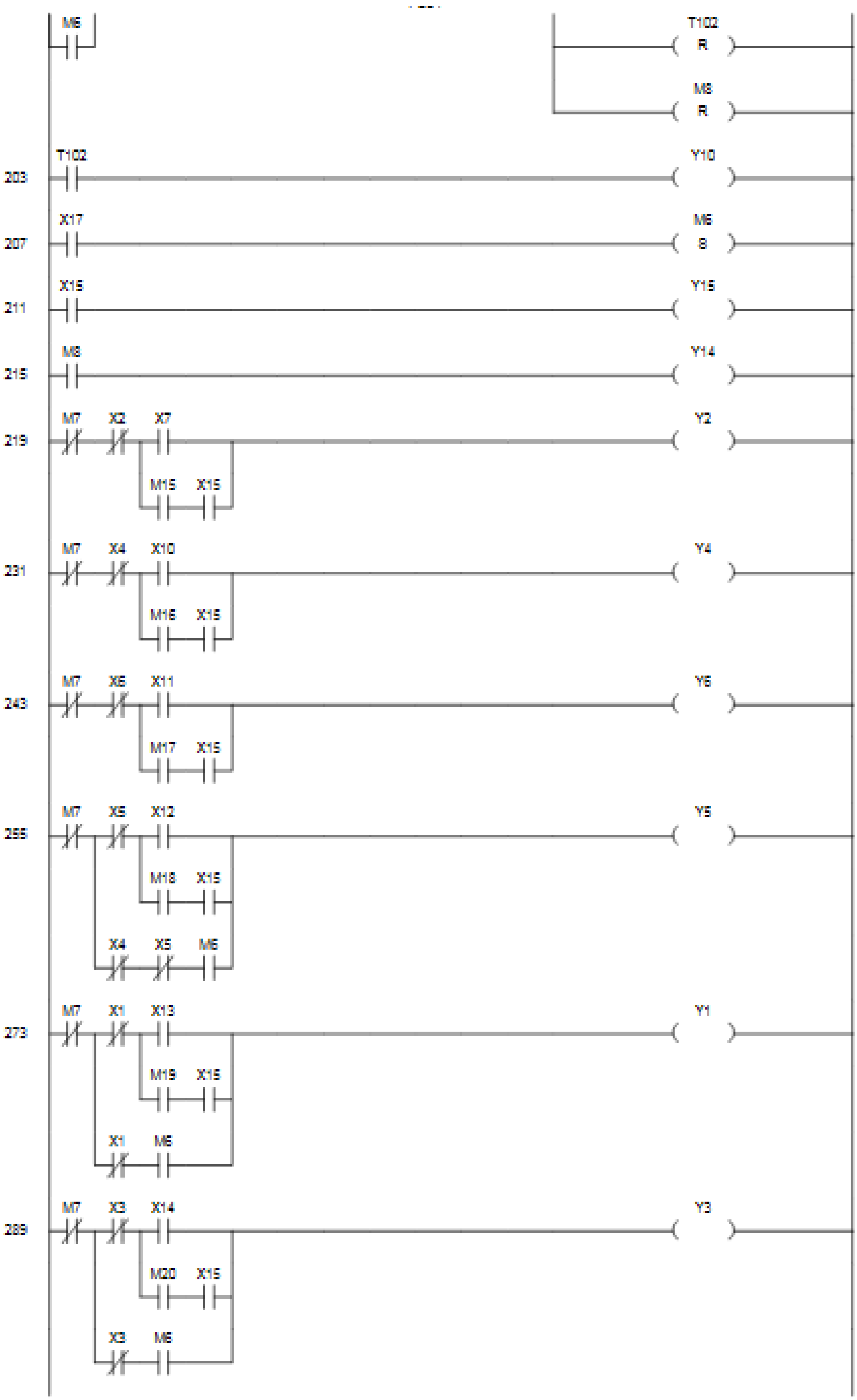
	operation
M17	Second stage compression valve operation
M18	Second stage return valve operation
M19	Door open valve operation
M20	First stage return valve operation

Timers

Timer	Definition
T100	Returning of first stage and door open
T101	Cycle start
T102	Cycle start with alarm (bell)




PLC1
120
M2
X15
T100
K40
127
T100
M4
S
M5
S
133
X15
M4
M19
S
139
X15
M5
M20
S
145
M6
X3
M20
R
M5
R
153
X1
M6
M4
R
M19
R
161
X1
M6
T100
R
167
X15
X16
X7
X10
X11
X12
X13
X14
M7
S
185
M7
Y7
189
X17
M7
R
193
M0
T101
R


M6
T102
R
M8
R
203
T102
Y10
207
X17
M8
S
211
X15
Y15
215
M8
Y14
219
M7
X2
X7
Y2
M15
X15
231
M7
X4
X10
Y4
M16
X15
243
M7
X6
X11
Y6
M17
X15
255
M7
X5
X12
Y5
M18
X15
X4
X5
M6
273
M7
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M20
X15
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M6

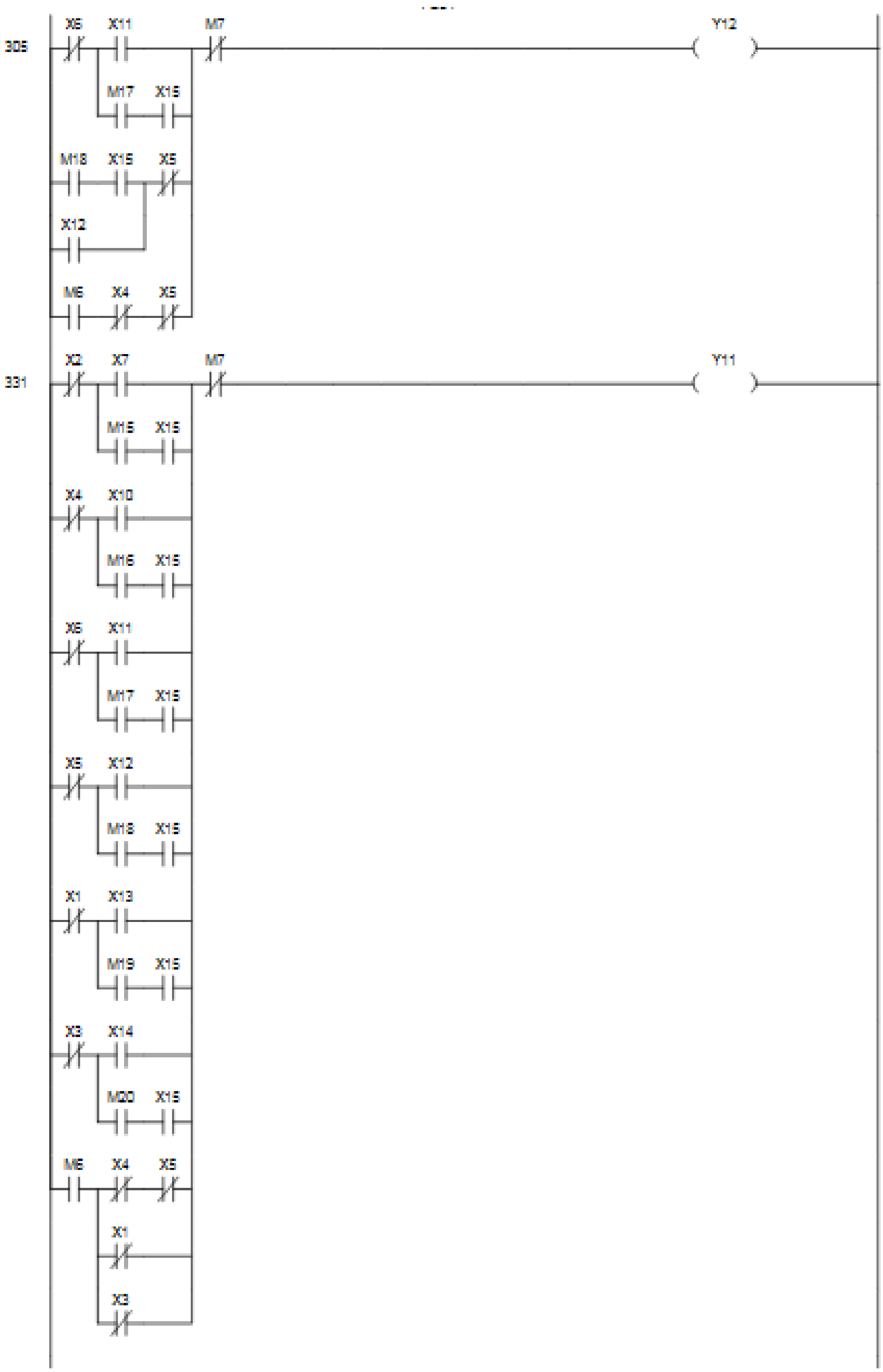

Figure A: Ladder diagram for PLC