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The Determination of the Performance of the Domestic Production Slant Boom Type Endless-Chain Excavator (Trencher)

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Abstract: The objective of this study was to reveal technical specification and operating characteristics of locally designed slant boom type endless-chain excavator (trencher). For this purpose, the trencher was tested to evaluate the quality of work at loamy-textured soil but in 3 different fields: compacted untilled soil, garden plat and stubble field after maize harvesting. Trencher which can be powered by 34.6 kW tractors, excavates 161-192 m/h and 1 m depth channel depend on the varying soil condition. The variability of channel depth was clearly high comparing to others in the field covered by harvest residue,
Key words: Endless-chain excavator, performance, trencher

INTRODUCTION

Drainage is an important problem in Turkey. 7.51% of agricultural area (5.86 million ha) are affected in different degrees of drainage problem. 1.97 million hectares of this area (2.52%), inadequate drainage, 3.9 million hectares (4.99%) has a problem of poor drainage. Part of this land is located in coastal areas and requires a pumping for soil reclamation.

Subsurface and surface drainage is the oldest, most widely accepted, and usually the most economical method of removing excessive water from the land. Drainage is very important in humid climate. On the contrary, irrigation is the most important measure of arid regions in the same way. In general, drainage measures should be taken in every irrigated area.

Construction of open ditches or underground channels requires laborious and expensive work. In drainage work, mechanization is recognized in Germany, Great Britain and the United States. In developing countries such as Turkey and Egypt which labour costs are relatively low, mechanized drainage work is also accepted. The purpose of soil drainage is to drain the excess water in the soil. Water in the soil in excess of the field capacity restricts the aeration of the soil and inhibits plant growth, and soil microorganisms.

Excess water in soil layer is not the only reason for insufficient soil aeration. Larger than 50 micrometers pores which helps drainage and improve soil aeration. The micro pores in which water tightly held is known as the reason of insufficient soil aeration. This kind of land defined as wet sticky soils. In this kind of land, drainage facilities, deep ploughing and loosen by sub soiling should be used together. Therefore, in the German DIN Norm (DIN 1185) the soil drainage classified as tiled drainage, surface drainage and surface melioration. Figure1 shows the drainage factors, the type of drainage depending on the cause of soil moisture, and the modern drainage methods.

Tiles and perforated pipes are usually installed either by hand digging or with trenching machines. Labour requirement for the construction of subsurface drains by hand digging has shown in Table 1. 2677 Person working hour is estimated using the values given in Table 1 for the constructing a 1000 m long and 1.5 m depth drainage system. This example is giving for constructing of tile drain system by hand digging on clayey soil texture conditions in Egypt.

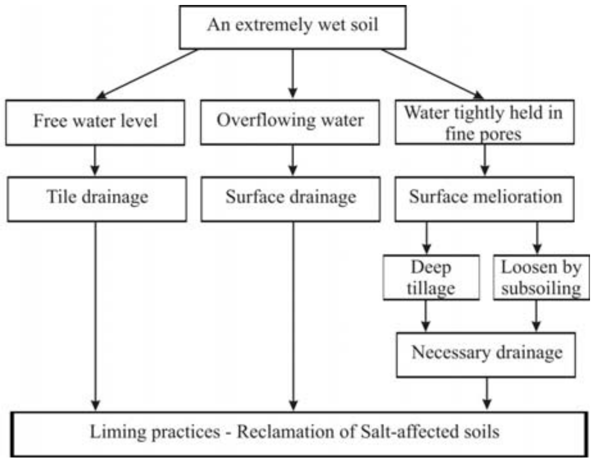

Figure 1. The use of modern drainage methods depending on soil moisture (Wolff, 1987)

Table 1. Labour requirement for the construction of subsurface drains by hand digging (Wolff, 1987)

1- Trench excavation				
Soil structure	**Max/min trench width (cm)**	**Depth of trench (m)**	**Excavated soil m^3 per m trench length**	**Labour requirement m^3 soil per labour hour**
Clay	36/30	1.25	0.41	0.29
Loam	45/30	1.25	0.45	0.31
Sand	55/30	1.25	0.54	0.50
Clay	47/30	1.50	0.57	0.26
Loam	52/30	1.50	0.63	0.33
Sand	65/30	1.50	0.71	0.46
Clay	55/30	2.00	0.86	0.21
Loam	60/30	2.00	0.90	0.30
Sand	75/30	2.00	1.05	0.42
2- Transportation, refilling the desired grade, levelling: 12- 15 m trench length per labour hour				
3- Laying the tile: 90-120 tiles per labour hour or 27-36 trench length per labour hour.				
4- Blinding and back filling: 1/6 of excavation time requirement				

Trench excavation (1), 2192 working hour; transportation, refilling the desired grade , levelling (2), 83 working hour; laying the tile (3), 37 working hour, and blinding and backfilling, 365 working hour has share in total labour force consumption. These calculated values are valid if organization conditions are good, the adult workers are sufficient for proof of hand tools. In general, the workers dig channel wider than needs. Therefore, labour cost for excavation and refill increases. Hand digging productivity is very small, construction period is also long. For this reason, hand digging is the most applicable for small jobs, for repair and maintenance of existing drainage systems and for installations where soil and climatic conditions will not permit the use of machinery. Generally, hand tillers can work under more adverse soil conditions than is possible with machines.

Trenching machines may be divided into four general classes: (1) plows and scoops, (2) wheel excavators, (3) endless-chain excavators, and (4) hoe excavators, as shown in Figure 2.

Plows and scoop-type machines are sometimes used to loosen the soil so that it can be removed more easily by hand. However, the type shown in Figure 2 carries the soil out of the trench on a conveyor. Wheel excavators are the most common type. The soil is carried to the top of the wheel and then dropped onto a conveyor belt. Endless-chain excavators may be subdivided into two groups: the vertical-boom and the slant-boom type. The vertical-boom type reduces the amount of handwork where obstructions, such as pipelines or cables, are encountered. The digging bucket of the hoe excavator (back-hoe) is simply a concave blade of the desired width. This class of excavator is suitable for making deep cuts, removing large stones, and making junctions. They also work satisfactorily in wet subsoil.

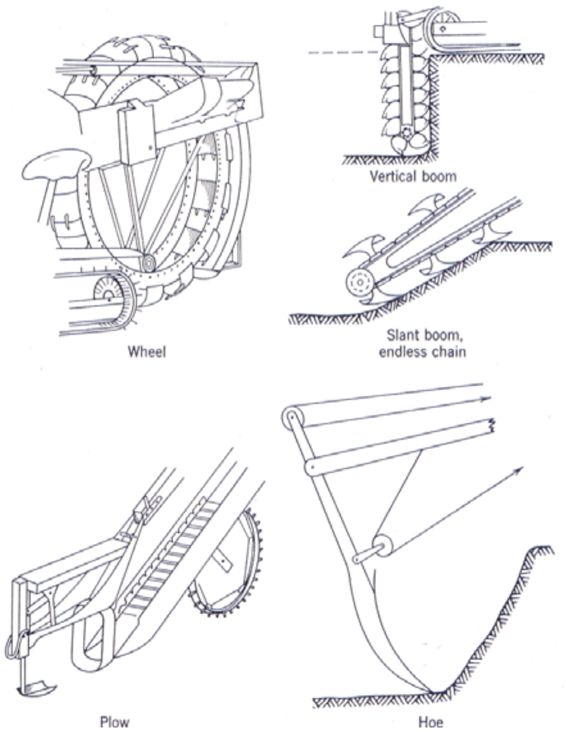

Figure 2. General classes of trenching machines (Frevert et al, 1955)

A trenching machine should dig a trench to a uniform grade under a variety of soil conditions. A crumber (shoe) following the digging mechanism is helpful, as it obviates the necessity of hand finishing the ditch bottom. To ensure good bedding conditions and to align the tile, the crumber should make a curved or V-shaped bottom in the trench. If the shoe is curved, a keel for making a groove should be attached to the bottom. Machines not equipped with facilities for maintaining grade should not dig closer than about 15 cm to the grade line, and the bottom of the ditch is being finished by hand.

The factors that influence the rate of installation for a trenching machine are: (1) soil moisture; (2) soil characteristics, such as hardness, stickiness, stones, and submerged stumps; (3) depth of trench; (4) condition of the trenching machine; (5) skill of the operator, (6) width of the trench; and (7) delays due to interruptions during operation. An extremely wet soil may stop machine operation; soil with a low moisture content may not affect the digging rate to any extent. Increasing the depth from 90 cm to 150 cm decreased the digging speed by 56 per cent under Iowa and Minnesota conditions (De Vries, 1951). A ditching machine operated by the contractor in northern states (USA) can be expected to install tile only about 150 working days during the year. Studies showed a total of 66.2 per cent of the available working hours were lost. This time lost is accounted for as follows: weather 18.6 per cent, repairs 14.0 per cent, making junctions 10.1 per cent, miscellaneous 9.3 per cent, moving from job to job 8.2 per cent, and servicing of the machine 6.0 per cent.

Figure 3 shows the blade type of slant-boom type endless-chain excavators. The blade type could be changed suitable to the soil conditions. The important advantage of endless-chain excavator are: breaking of the soil mass into small pieces; bringing the fragmented soil to ground surface; and pushing the soil mass both left and right side. Trench width could be adjusted by mounting the blade in different positions. After tile lying, backfilling of the tile trench can be accomplished with many machines such as two counter acting helicoidal spiral, bulldozers, hoes, graders, manure loaders, and blades on small tractors (Wolff, 1987).

Figure 3. Blade types of slant-boom type endless-chain excavators (Gallwitz, 1961) a) For normal-cohesive soil, b) For pebbly or frozen soil, c) For stony soil.

MATERIALS and METHOD

Soil and Slant-boom Type Endless-chain Excavators

Field trials were conducted in sandy loam soil in Turgutlu. The area is located at 30 km south-east of Manisa. The average annual temperature is 16.9 ºC and precipitation is 515.1 mm. Soils were formed over alluvial deposits within Gediz Basin. Trencher treatments in the same plots were: a) compacted field road (soil moisture 4%), b) maize field after harvesting (soil moisture 15%, stubble height 29.26 cm (CV = 6.49%), row spacing = 70 cm), and c) orchard (soil moisture 9.4%).

A slant-boom type endless-chain excavator (trencher) was used in the fields study. Maximum trench depth was 120 cm. Trench width could be adjusted between 15 to 30 cm by mounting the blade in different positions (Figure 3a, b). Slant-boom type endless-chain excavator was powered by MF 240 S Model 34.6 kW (47 DIN PS) tractor.

Figure 3 a. Engagement of the trencher in field (without security frame attached)

Figure 3 b. Trencher with a security frame attached

Main frame is made of 750*1000 mm vertical montage segment and 165*200*385 mm box profile which carries the impelling power shaft. The box profile is mounted to vertical montage segment via four screws. Box profile is made of 12 mm slab. The wheels are attached to the vertical frame by welding; the level of the wheels can be adjusted by using screws.

Slant-boom type endless-chain: impelling power shaft of endless chain bearing on the box profile. The slant-boom is attached to box profile and its movement is allowed in a pivot joint (Figure 4). Hence, the angle of the boom can be adjusted by employing a hydraulic cylinder, which is attached between vertical montage segment and the box. The slant-boom is telescoping boom (dimensions: 55*135*1420 mm) and tension of the chain can be adjusted.

Figure 4. Linking Slant-boom type endless-chain to main frame

Blades (Figure 5) are fixed to endless-chain via two screws. Altering the fixing position of blades, 0.15-0.30 m channel width can be reached.

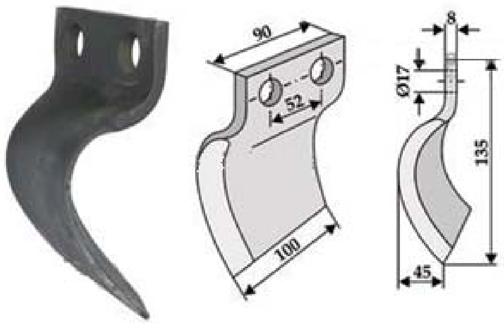

Figure 5. Trencher blade

Power transmission system (Figure 4): the power is transmitted to endless-chain using gear box to decrease the rpm in a ratio of 1/2.5. The output shaft of gearbox has overload pin for preventing the damage of machine. The pto shaft also has friction coupling.

To prevent soil pouring into opened channel after excavation, two spiral conveyors (right and left) are mounted to main frame of slant-boom via bolts. Gear, which drives the spiral conveyors, is powered by endless-chain.

Figure 6. Spiral conveyors

Safety frame (Figure 3b): in order to avoid spreading of stone and other materials during the excavation process, safety frame (covered with canvas) is designed. The frame is assembled to vertical montage segment of trencher. The frame is stabile and is not moving with slant-boom, which ensures working without negative effect of channel curve. Figure 7 reveals the machine without safety frame of trencher and spreading of soil and stones at work.

Figure 7. Trencher, spreading stones and soil without safety frame

Technical specifications: The weight of trencher is 870 kg. Trencher has 4600 mm length, 92 links with 50 mm screw pitch endless-chain. Some technical specifications are given below:

Spiral conveyors (left and right):

Diameter: 350 mm

Pitch: 350 mm

Drive gear teeth: 11-15 pieces

Transmission ratio: 0.48

Rpm of conveyor: 259 min^{-1}

Forward speed: 1.51 m s^{-1}

Blades (Figure 5):

Width of channel: 0.15-0.30 m

Material: 60 Si Mn5 steel

Hardness: 47-49 RSD-C

Method

After technical expertise in laboratory condition, trencher was tested for performance examination in field conditions in Turgutlu. Tests were conducted at loamy-textured soil but in 3 different fields (Table 3). Effective field capacity of trencher and quality of work were evaluated. The capacity, m channel/h and excavation yield, bm^3/h were calculated.

RESULTS and DISCUSSION

The trencher can be employed to excavate channel, to install the tile in stony and compacted soil within the depth limit given in Table 3.

Trencher, depend on the soil condition, can excavate 161-192 mm length channel at 1 m depth. Taking the value of time utilizing value as 60 min/h, yield per hour (considering natural soil volume) were calculated 40.61-51.45 bm^3/h (Table 3). In the field covered by corn residue, the variability of channel depth was clearly high comparing to others.

Trencher can be powered by 34.6 kW tractors. Safety frame secures people behind the machine from stones and soil injuries. Due to its montage advantage, it is not affected from channel curve at work. In Turgutlu, trencher can be employed 7 months in a year and be used at additional jobs. While working with trencher, chain tensioning must be checked time to time.

Table 3. Trencher working speed and capacity values in different soil condition

Field conditions	Channel depth (mm)	Channel width (mm)	Soil hillside height (mm)	Speed (m/h)	Field capacity m canal/h	Excavation yield (bm^3/h)
Compacted field road	1052 ± 10.45$^+$ CV = %0.18	255.7 ± 6.15$^+$	400 ± 5.77$^+$	192.0	192.0	51.41
Field covered by corn residue	825,3 ± 50,0 CV = % 10.49	306.0 ± 6.20	365 ± 7.64	160.8	160.8	40.61
In orchard garden	1027,6 ± 23.45 CV = %3.95	270.9 ± 7.51	454 ± 3.05	171.1	171.1	47.47

$^{+)}$ Standard error

CONCLUSIONS

The followings were concluded from the study:

When value of time utilizing is taken as 60 min/h, the trencher can excavate 161-192 m/h and 1 m depth channel depend on the varying soil condition. The excavation yield, as natural volume, is calculated as 40.61-51.45 bm^3/h. DeVries (1951) gave the rate of trench excavation for wheel-type machines at 1.2 m of trench depth 93 m h^{-1} for continuous operation including 70 per cent time lost due to weather, repairs and servicing, junctions, moving machines, and miscellaneous. He indicated that increasing the depth from 0.9 m to 1.5 m decreased the digging speed by 56 per cent.

The trencher can be powered by 34.6 kW tractors and moved in highway in safety. Trench width of slant-boom type endless-chain excavator (30 cm) was suitable to installation pipe or dren tiles. Although the width of the trench may not be important for machines with sufficient power, the rate of installation may be reduced especially for trenches wider than 40 cm.

Safety frame, keeps away driver and working people behind the machine from stones and soil while working.

When working with trencher, chain tensioning must be checked periodically. Attaching automatic tensioning mechanism to trencher may prohibit machine damages and save time.

Regardless of whether the trench is dug by hand or by machine, the three principal ways of establishing grade are the line, sight and laser controlled methods. Laser grade control system facilitates the establishing the true grade. Laser controlled grade system improves the tile laying capacity of the endless chain excavator 50 per cent (Wolff, 1987). For this reason, laser grade control system has to be combined with the slant-boom type endless-chain excavators.

However, if the parcel is level, laser grade control system could not be used. The forward velocity and trenching capacity of machine is 10 to 15 per cent higher on levelled field than unsuitable topographic conditions (Wolff, 1987).

If for some reason the trench is excavated below grade, it should be refilled to the desired grade, with well-graded gravel. If the trench does not have water in it, wet soil may be suitable if thoroughly compacted under the tile.

Trenching machines have been used to modify profiles to greater than normal depths. These machines thoroughly mix the soil profile to a depth trenched but is prohibitively expensive for use in field crop production. The use of a trencher may be economically feasible for growing special purpose crops such as grapes on mechanically impeding soils.

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