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Recent Trends In The Manufacture And Use Of Extruded Clay Sewer Pipes

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Introduction :

One of the major advantage of clay pipe is the very fact that it is made of clay. Vitrified clay pipe and fittings are used for the conveyance of sewage, commercial and industrial wastes, chemical liquids and vapours and storm water. The competition between clay and concrete pipe is extremely tough especially when it is a question of pipe for sewers. The vitrified clay pipes and fittings are increasingly being used and recommended by Municipalities, Consultants, Contractors and drainmen in many developed countries like USA, Soviet Union, Britain, Canada, Germany, Japan, Newzealand, Mexico, Denmark etc. etc., due to ease in installation, complete water tightness, resistance to root penetration and continuous trouble free service. As compared to concrete pipes, the vitrified clay sewer pipes are not attacked by organic acids and bacteria. A big contribution towards maintaining a lead of extruded clay sewer pipe over other materials in the last three decades has been made by clay working machinery manufacturers who have steadily modernised their equipment to reach a higher level of production and at the same time reduce both production and labour costs. It is now realised that it is only the extrusion phase in the manufacturing process which greatly influences both the level of production and the cost factor. Due to application of standard sizes in most countries it has been possible to develop fully automatic production lines for the manufacture of stiff extruded pipes of various sizes. At present extruded pipes are manufactured in sizes ranging in diameter from 4 to 42" (10 to 106 cms) and upto 10' (3.048 m) in length. Trend is towards manufacturing larger diameter and longer pipes, the reasons for greater lengths is for improved efficiency due to fewer joints in installation in addition to enhanced rate of production.

Although, both socketed (or bell) and plain-end extruded clay pipes are being manufactured but nearly all the clay pipe producers now are manufacturing, experimenting or taking another look at plain end pipe. In USA practically all pipe manufacturers have switched over to plain end pipe. The reasons are apparent; (1) better consumer acceptance because it is easily installed (2) flexibility in use and (3) simplified production Process. With the introduction of special flexible mechanical couplings the plain end pipes are becoming popular due to enormous savings in production costs as well as ease in installation as compared to socketed pipes. This paper gives a brief review of recent developments in the manufacture and use of extruded vitrified clay sewer pipes in American continent with particular reference to Canada.

2.0 Technology of Production

The production technology adopted in the manufacture of all burnt clay products is very similar. Clays must be selectively mined and processed. It must then be formed, dried and fired. Due to low selling prices of clay products the economic viability of modern ceramic plant is mostly dictated by the production process employed for the forming and processing of raw materials which are responsible for the development of very efficient machines and automation of production line. At present, in an automated plant, clay pipes are formed universally by extrusion adopting dry processing of materials which affords both, the efficiency as well as optimum use of energy, a prerequisite for any economically sound clay products plant. In the past, experiments [1] were conducted in Soviet Union to develop other production processes for the manufacture of clay pipes such as semi dry pressing and by "grafting" (the process of building up the article by applying layers of clay on top of each other) but these could not be commercialised economically.

The production technology for extruded clay pipes, using dry grindring, has been shown diagrammatically in Fig. 1. It has essentially five phases i. e. mining and storage of raw materials, mechanical preparation, extrusion of green pipes, mechanical finishing and handling of green pipes, drying, firing and testing.

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2.1 Mining of Selected Clays and Its Storage

The finest and most upto-date equipment can not make good pipes unless the clay is right. In the manufacture of clay pipe virtually nothing is added but a little water to give the clay plasticity during the forming stage. Clays are composed basically of silica and alumina with other minerals present in small quantities. The manufacturing characteristics and the final product depend upon the proportion in which these minerals are found in raw clay.

Rarely any sewer pipe is manufactured from a single type of clay. The raw material is generally the mixture of a plastic clay and a non- plastic aggregate (grog of lean clay). In the States it is a general practice to mix fire clays and shales to obtain desired product characteristics of strength, chemical resistance, dimensional control, low porosity etc., demanded by the consumer. Fire and refractory clays are resistant to heat and are used in large quantities in the the "Clay pipe" industry because they do not deform at high temperature and thus give good dimensional control to the finished product. So called " Multicomponent" batches compiled from different types of clays with properties which supplement each other give high quality bodies (raw material). Multicomponent batches are often used for the manufacture of large diameter pipes.

The selected clays and shales are stripped with power equipments like front-end loader or power shouels and trucked into the plant. In preparation of batches at some plants different clays are mixed at the mines itself whereas in others it is blended from storage bins. Batch mixes are carefully worked out in the laboratory. A typical mix being used at a plant consist of shale refractory clay and grog in the ratio of 60%, 30% and 10% respectively. Each of the raw material is crushed separately to a maximum of 3″ lump size through a double roll crusher. The crushed material is conveyed to a storage building and distributed by a shuttle conveyor.

2.2 Mechanical Preparation of Raw Material

The objective of mechanical preparation is to present the raw material in a suitable form at an acceptable rate for futher processing. It is usually done by machines by actions such as rubbing, pressing, mixing and other processes. The pipe body can be prepared by the plastic or dry method. The plastic method of preparation especially in clay pipe industry has become outdated as it suffers from drawbacks such as clay is poorly mixed, mechanization is difficult and good quality pipes are not obtained by this technique. In most of the plants, it is common practice to prepare clay bodies, using dry preparation and extruding with low moisture content (upto a maximum of 18%). This helps in protecting the pipes from damage due to high air shrinkage and reduce drying time and fuel consumption as compared to plastic preparation (19.5 to 21% moisture).

Three ingredients, shale, fire clay and grog maintained in hoppers are fed into the rim discharge type of grinder in fixed proportion with the help of apron feeders. The charge is ground (8-10 mesh) fine enough to fall through the performations in the metal pans. The ground materials are then elevated by troughing conveyors to a battery of heated vibrating screens. The fines from screens are taken by conveyor to storage bins while tailings, together with the scalper oversize is conveyed to the grinder forming a closed circuit grinding [2]. The ground raw material is distributed to extruders by means of belt conveyors through feed hoppers automatically. The waste products formed during extrusion, drying and firing are recycled by feeding into the crusher.

2.3 Extrusion, Finishing and Mechanical, Handling of Green Pipes

The extrusion process, as practiced universally, is used for the manufacture of clay pipes. Both horizontal and vertical extruders are employed but horizontal extruders are preferred for the rapid production of small diameter pipes. In the past the vertical machines were mostly steam driven intermittent piston presses, but except where hydraulic pressure is used to drive the pistons, they are largely superseeded by auger machines. In the auger machines it is possible to incorporate a deairing system which increase the plasticity of the clay and makes the extruded pipe less brittle.

Most of the up-to-date plants incorporate sturdily built auger extruders, both horizontal and vertical, the most common being Steele, FRH, Bonnot, Fawcett and Craven makes, consuming upto 500 HP. These machines have been perfected by the incorporation of electronic measuring and timing controls which have solved many production problems. Very stiff extrusions (12 to 15% moisture) has been obtained by using hard wearing alloys (containing 28% chromium) in the manufacture of worms, liners, knives, electrically acti-

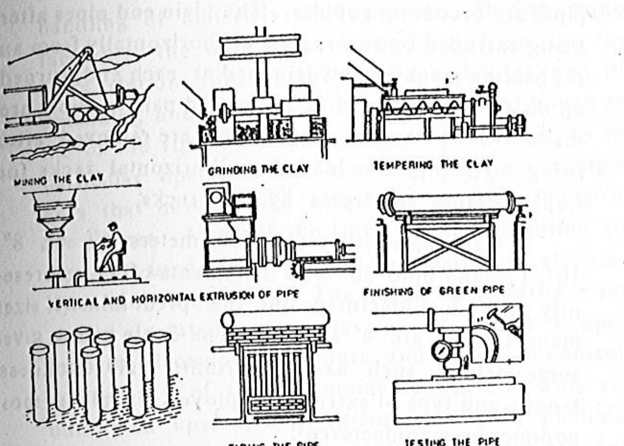


FIG 1 STEPS INVOLVED IN THE MANUFACTURING OF EXTRUDED CLAY SEWER PIPE

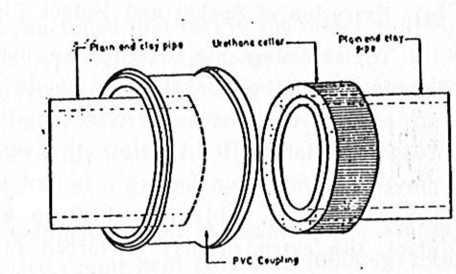


FIG 3 JOINTING OF PLAIN END PIPES WITH FLEX-LOX COUPLING

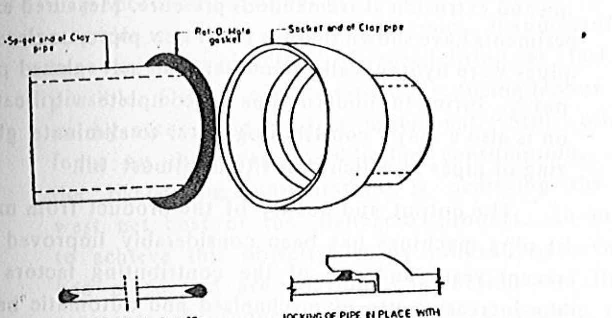
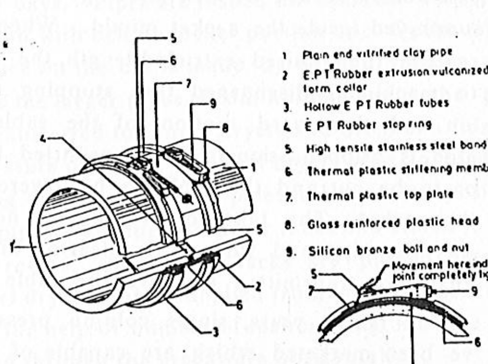


FIG 2 FIELD APPLIED JOINTING OF SOCKETED PIPE WITH ROL-O-MATE GASKET



PLAIN END FLEXIBLE RUBBER COUPLING

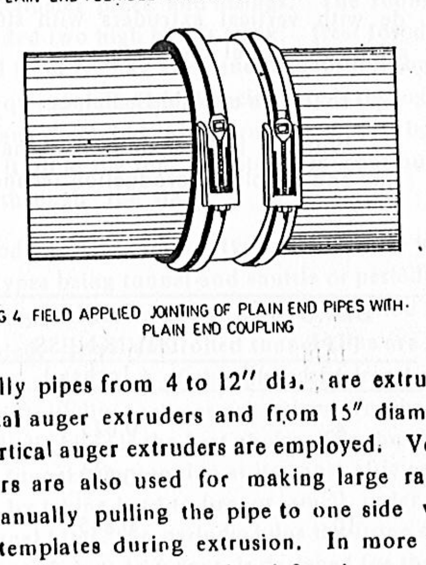


FIG 4 FIELD APPLIED JOINTING OF PLAIN END PIPES WITH PLAIN END COUPLING

vated pneumatic clutches, sophisticated lubrication system in addition to single reduction separate drives for pug sealer and extruder. The separate drive deairing machines offer a distinct advantage while manufacturing clay pipe since extruder auger shaft needs stop and start with the formation of each pipe, thus the tempering of clay is much more efficient due to continuous pugging. It has also been observed that when total power for both drives exceeds 250 HP, the splitting of this load into two entirely separate drives is mechanically more feasible for strenuous requirements involving low moisture content and high output. In another vertical pipe extruder marketed by British firm "Rawdon" the vacuum chamber is equipped with ultrasonic feed control system which limits the amount of clay contained in chamber[8].

Generally pipes from 4 to 12" dia. are extruded on horizontal auger extruders and from 15" diameter onwards vertical auger extruders are employed. Vertical extruders are also used for making large radius pipes by manually pulling the pipe to one side with the aid of templates during extrusion. In more recent extruders special dies are fitted for the manufacture of curves, elbows and traps from 4 to 10" diameter. Although, pipes of larger diameter are exclusively made on vertical extruders, but the latest trend is towards the employment of horizontal extruder for larger diameter pipes as well. The clay pipes as extruded by auger are of two types.

(a) Socket and Spigot Pipe

(b) Plain End Pipe

(a) **Extrusion of Socket and Spigot Pipes**

The extruders are designed to make these pipes in one piece, the socket being made integrally with the pipe by means of electro pneumatic press table. The press table, fitted below the vertical extruder, moves up and down having a bolted mould for socket. When the table is locked up against the die plate, the extruded clay is forced into the socket mould. After this has been filled, the table is released and the extruded pipe gradually presses the table down. To overcome the internal stresses developed during socket or bell forming a lubricating oil is sprayed inside the socket mould. When the table reaches the required extruded length, the main drive to machine is disengaged thus stopping the extrusion and downward motion of the table. As the pipe is gripped, signals are transmitted for the pipe to be cut and the table to be lowered to clear the socket. The take—off equipment now withdraws the pipe and when it is clear off the table, signals are transmitted to drive the table up.

In recent years, single column press tables have been marketed which are capable of high speed production upto 10 pipes per minute of 4″ dia and 3.3′ length[3]. Smaller diameter pipes are also made with vertical extruders with simultaneous formation of several pipes[1].

(b) **Extrusion of plain End pipes**

With the introduction of mechanical flexible jointing and simplified production technology due to absence of any socket or bell, the plain end cylindrical pipes are becoming popular. The plain end pipes after being extruded by auger, rolls off horizontally from an off bearing machine and trimmed at each end, turned up on end and grouped on perforated pallets. Pipes are made with their own rings which are removed after firing. The pipes are loaded on horizontal racks for transportation to dryers by lift trucks.

In Canada, mostly pipes of diameters 4″, 6″, 8″, 10″, 12″ and upto 36″ with increments of 3″ are presently being manufactured but the predominant sizes manufactured are 4″ and 8″. The Table below gives some details, such as output/shift, wall thickness, length and type of extruder employed for pipes most commonly manufactured[7]:

In the past (upto late 60's) it was the practice to apply interior spray glazing in clay sewer pipes but this has been completely dispensed with as it is regarded unnecessary due to smooth finish resulting from fine grinding and extrusion at tremendous pressure. Measured experiments have shown that for clean new pipes, unglazed pipes were hydraulically smoother than salt glazed pipes [4]. Firing in modern kilns to complete vitrification is also a major contributing factor to eliminate glazing of pipes in which porosity is almost nil.

The output and quality of the product from most pipe machines has been considerably improved in recent years and one of the contributing factors is the increasing use of mechanised and automatic handling equipments. The heavy clay industries, particularly pipe industry, is encountered with complex

DIA.OF PIPE (Inches)	WALL THICKNESS (Inches)	OUTPUT PER SHIFT (Feet)	LENGTH OF PIPE (Feet)	TYPE AND DIA.OF THE AUGER EXTRUDER
4	0.625	7500	4	HORIZONTAL EXTRUDER 13″ INCH DIA. AUGER
8	0.750	5000	4.6	
10	0.845	4500	5.3	
12	0.937	3000	6.3	VERTICAL EXTRUDER 18 INCHES DIA. AUGER.
15	1.5	2500	6.3	

handling of materials and products. During manufacturing, the ware must be handled from the forming station, through the dryers and kilns and the unloading and packaging departments. Although some of the equipments have been customized to the particular operation but in many instances equipments that have proved successful in other industries are in use. Most of the finishing and handling equipments used are operated pneumatically, electrically and hydraulically. The trend is towards electrically operated equipments since it is easy to apply modern electronic techniques and precision controls. A majority of these equipments operate with vacuum pick ups. Where extrusion is soft, pneumatically operated grabs are applied but these are considerably slower than vacuum type pads.

2.4 Drying and Firing of Green Pipes

Heat is the key medium for maturing heavy clay products and its application is the heart of ceramic process. Some ceramic manufacturers have primary objective of speed-firing as fast as possible. Others concentrate on reducing labour costs by automating product movement. Still others focus on the lowest possible fuel consumption. But the over-riding consideration is achieving the lowest net cost of the ,delivered product. In order to achieve this objective many innovations have taken place and are continuing in drying and firing segments of production process by automatic setting and unloading of ware, more uniform burning, greater use of waste heat anreducing the rejects.

To assess and guide the clay sewer pipe industry in USA, an investigation[5] was carried out by IIT Research Institute, Chicago (Sponsored by National Clay pipe Institute, USA) to compare energies required to produce pipes of different materials. The investigation was intended to encompass the various fabrication process including the raw materials and concluding with yard storage or stock piling of finished products in a form ready for shipment to customers.

Result of this is given below (for 8″ pipe) :

Material	Energy (BTU/Ft)
PVC (Poly-Vinyl chloride)	146160
ABS (Acrylonitrile-Butadiene-Styrene)	92820
Cast Iron	523000
Concrete	72960
Cement Asbestos	279980
Clay	77685

It was concluded that fuel is the major source of energy. To improve overall energy efficiency it is essential to have better combustion, more effective insulation from heat loss or transmission and also trapping of waste energy from the kilns for recycling it to the dryers.

In an automated plant, the moist pipes are dried in large heated rooms kept at 150° F (holding rooms) under controlled conditions of temperature and humidity. Moisture should be removed as quickly as possible although in case of large diameter pipes it may take 3 to 7 days. Pipes are loaded on kiln car in vertical position with bell or socket portion up. Optimum use of space on the car is made by nesting smaller pipes inside the larger pipes. From holding room the pipes are transferred to tunnel dryers and dried at a final temperature of 300°F. Tunnel dryers are also used for drying 4″ dia. plain end pipes in horizontal position. The pipes are loaded on dryer racks and stored in holding rooms. As required racks are pushed into the tunnel dryer, heat is supplied from inclined burner and with the help of number of recirculating fans the air is forced through the greenware horizontally.

Batch type dryers are especially employed for drying large diameter pipes and fittings. The room dryers are loaded two high by lift truck. Heat for drying is supplied from cooling kilns and combustion chambers when required. The air is recirculated through the dryer by fans which blows in warm air at the bottom and takes it off at the top. Waste air is continuously released through the stack.

In modern plants several types of kilns are in use, the chief types being tunnel and shuttle or periodic kilns. For high capacity and efficient production fully instrumented, panel controlled tunnel kilns are invariably used for the firing of clay pipes of almost all sizes. When flexibility becomes prime concern, the shuttle or periodic kilns is the best choice. The shuttle kilns keep the tunnel kiln running at its most efficient rate and cycle by taking hard to fire, or small order items out of tunnel kilns. In periodic kilns the firing cycles, varying from 2 days to 6 days, is designed for the specific product rather than a compromise cycle dictated by tunnel kilns. Most of the plants use Swindell Dressler, Harrop tunnel kilns and Bickley Shuttle Kilns fired with natural gas, oil or a combination.

The greater portion of smaller sizes of pipes are fired in tunnel kilns [2]. The dryware is set on tunnel kiln car (8′ wide x 10′ long) and settings are 4′ and 6′ high. The cars first enter a reheater and heated upto

300° F. After preheating the car is pushed into kiln, where it passes through zones of increasing heat and vitrified in firing zone at a temperature of 2030 to 2320°F. A tunnel kiln fired with natural gas employing high velocity burners has a firing cycle of 40—46 hours, both the attainment of maximum temperature and cooling share this time equally. The cars are dehacked manually and palletized on return tracks.

The periodic kilns are used in firing larger diameter pipes and all sizes of fittings. New shuttle kiln design that combines highly efficient fiber insulating refractory lining in a lightweight steel shell structure with full down-draft firing, has been very successful in the clay pipe industry. By having total control of the firing cycle, the modern periodic kilns are equipped with latest controls and instrumentation such are computer systems and microprocessors. As reported above 8" sewer pipes are now being jet fired in precision "Bickley Shuttle Kilns." In a 50 hour cold to cold firing cycle, 80 tons of top quality pipes and fittings are produced[6].

3. **Jointing of Pipes**

Vitrified clay sewer pipes are jointed using both flexible and nonflexible joints. The basic requirement for jointing material is that it should be chemically resistant and stable. The traditional nonflexible jointing materials like cement mortar and precast bituminous strip has been completely discarded. At present flexible joints are universally used due to inherent advantages, both in installation and maintenance, as it permits sufficient flexibility in torsion to allow considerable angular movement and/or axial misalignment between the pipe ends. Different pipe manufacturers have marketed a number of mechanical couplings for flexible jointing of pipes, both socketed and plain end.

a) **Jointing of Socket and Spigot Pipes**

The socketed pipes are jointed by socket or bell ends formed on the pipe in which usually a resin cast lining is made forming the internal diameter to a standard size. The spigot end of the adjacent pipe is inserted into the socket and a rubber ring is used to form a seal between the resin sleeve and the spigot. The rubber ring must be of standard section to accomodate the range of manufacturing tolerances of the socket, the resin sleeve and the spigot. The most popular coupling developed by different manufacturers used for jointing these pipes is usually of "0" ring or of other configuration. One of these, marketed by a firm bearing trade name "Roll 0 Mate" is described below.

Roll-0-Mate Joint[7]

It is a field applied joint (Fig. 2) for socketed pipe consisting of elastomeric sealing '0' ring when applied to the spigot end of the pipe and which after spigot is pushed into the socket, will form a seal between two clay surfaces. From engineering stand point, Roll-0-Mate design has all the sealing characteristics of an "0" shape plus the roll-over-and-lock advantage. The positive audible locking action is clear assurance of a tight seal. It has eliminated time consuming check backs and uncertainty. This type of joints are being used upto 15" diameter pipes. It does not require any grooves, adhesives, lubricants to put in place or to hold in place (socket). This type of gasket gives sufficient flexibility to move pipe for lateral alignment or to raise or lower for grading without its coming apart.

b) **Jointing of Plain End Pipes**

The socket or bell has always been considered the weak point in a clay sewer pipe line because of the every present possibility of damage from handling and installation in addition to problems arising during manufacturing stage. To overcome these difficulties, plain end-cylindrical pipes connected by an injection moulded plastic sleeve incorporating a small section rubber seal at each end were introduced. This type of joint has many advantages for both manufacturer and user such as elimination of socket forming process resulting in increase in production rates as well as reduction in rejects, lower breakage rates at site, easier and foolproof jointing, and all pipes can be cut and cut ends jointed. These advantages fully justify the cost of special flexible coupling for the plain end pipes. The two main types of flexible couplings for jointing plain end pipes marketed by manufacturers in their trade names are.

i) **Flex-Lox Coupling**[8]

This system of coupling (Fig. 3) includes a preformed PVC collar positioned on one end of the pipe and a moulded band of urethane formed on opposite end. Field installation is by friction fit of urethane band to PVC collar, permitting the ends of pipe to come together forming an all clay internal line. The connection is fully supported by the rigid clay pipe body which eliminates any of the problems associated with flexible conduit. Pipes from 4 to 15" diameter are manufactured with this type of coupling. Automatic equipment handles the pipe and pours the urethane on a mechanised turn table after which they are packed and put in yard storage.

ii) **Plain End Flexible Rubber Coupling**[8]

This is a flexible rubber coupling for plain end pipes which was marketed only after years of extensive research and testing. This coupling is extensively used with complete success on all pipes from 4 to 27" diameter. The plain end coupling (Fig. 4) consists of an extruded synthetic rubber collar(2) incorporating two hollow rubber tubes(3) vulcanized into circular section, sized to fit over the outside circumference of the pipes to be joined. Through the hollow tubes pass high tensile stainless steel bands (5). Each band is securely attached to the reinforced plastic head(8) at one end, while the other end passes through and crimped over the flat section of the silicon bronze bolt (with nut) (9). This bolt is contained in the head cavity or slot, along which it is free to move longitudinally. When the nut is tightened, the bolt is pulled forward. inducing tension in the band, and thus compressing the rubber under it directly to the pipe end. With both bands tightened, a positive seal from one pipe to other is accomplished.

4. Concluding Remarks

Industries in all segments of society are becoming increasingly concerned about the amount of energy required to produce their product by adopting appropriate production technology at minimum operating costs. Due to numerous advantages of the extrusion process with the provision of deairing, the unglazed clay pipes at present are being manufactured only by adopting sophisticated sturdily built auger extruders. The clay pipes with internal ceramic glazing manufactured by piston extruders have been completely dispensed with. With the introduction of automated kilns and shrink film packaging[2], the product in general is more consistent and of higher quality.

Vitrified clay pipes are increasingly being used for sewer system and other applications. With the introduction of plain end vitrified clay pipes the production problems have been reduced. Due to absence of socket, the extrusion has been simplified and accelerated, mechanical setting and firing perfected and because of plain cylindrical shapes the breakage in stacking and packaging has been reduced. The introduction of mechanical joints as discussed earlier has made great appeal to Users because these are relatively fool proof on site.

In developing countries like India, due to large construction activities the shortage of cement is likely to continue. Already some firms are producing socket type salt glazed clay pipe by extrusion. The introduction of plain end vitrified extruded clay sewer pipes along with time tested flexible mechanical joints, in place of traditional concrete clay socketed glazed pipes and non-flexible joints, has vast potentialities.

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