

## Modeling of Concrete Pipe Auto Gripping Jaw for Pipe Handling

Mr. Dhanesh M. Pawar<sup>1</sup>, Mr. Omkar Taware<sup>2</sup>

<sup>1</sup>Assistant Prof. Department of Mechanical Engineering, JSPM NTC, RSSOE&R, Pune

<sup>2</sup>Assistant Prof. Department of Mechanical Engineering, TSSM's, BSCOER, Pune.

Corresponding Author: Mr. Dhanesh M. Pawar

**Abstract:** Material handling plays a vital role in every manufacturing and construction organization. It has been estimated that more than 15 to 20% of the product cost is associated with material handling activities. Unlike many other operations, material handling adds to the cost of the product and not to its value. It is therefore important first to eliminate or at least minimize the need for material handling and second to minimize the cost of handling. Presently the concrete pipes are handled manually by use of crow bar and human worker which is time consuming, damages the pipes while transportation, unsafe work practice hence there is a need of concrete pipe suspender for fast and safe handling of concrete pipes. It is important to keep the pipes properly by lifting the concrete pipes. If the tool is prepared incorrectly, it may cause partial or total damage of the pipes. Worker safety conditions highlight the need of a proper gripping and lifting device for concrete pipe handling. Lifting and placement of the concrete pipes can be managed safely by the concrete pipe lifter equipped by jaws. Light weight, structure is simple, so the usage of it is very favourable. The concrete pipe can be kept lifted by turning the hanging force into clamping force.

**Keywords:** safety, economy, gripping device.

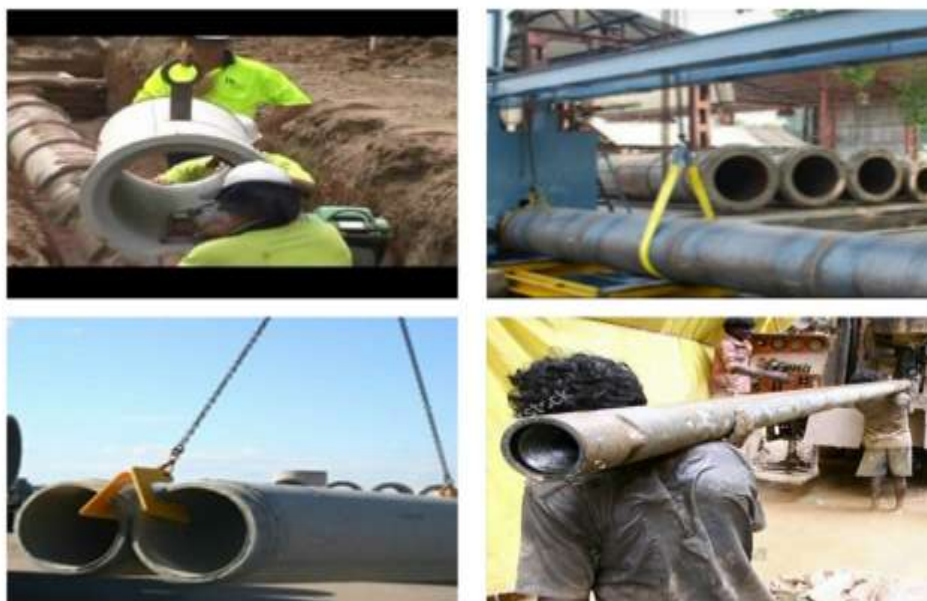
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### I. Introduction

Lifting and handling of concrete pipe is a main task in many industries and commercial work places. Concrete pipes are commonly used for rainwater drainage and sewerage in most civil works. There are various techniques available for handling of concrete pipes.

#### 1.1 Conventional method

In India many times the concrete pipes are handled manually by use of crow bar and human labour as shown in Fig.1. This technique requires 4-5 human labours for whole process of installation of pipe in the field. This is so time consuming process .It also damages the pipes while transportation. It is quite unsafe method of pipe handling. Conventional method of concrete pipe handling is shown in fig. 1



**Fig. 1 Conventional method of concrete pipe lifting**

Conventional concrete pipe lifting work process involves six steps

- a) Moving a crane to the site concrete pipe storage yard.
- b) Fastening a concrete pipe to a crane using a wire rope or chain choker and lifting up the pipe.
- c) Moving the pipe to a trench for installation.
- d) Placing the pipe and calibrating its position to be connected through the repetitive trial and error.
- e) Connecting and aligning the pipe and
- f) Adjusting the slope, if necessary.

During concrete pipe installing work, labors are exposed to the risk of accidents when they enter the trench to install pipes. There are safety issues in case of heavy weight concrete pipes. For example, a concrete pipe of 800 mm in diameter weighs about 1200 Kg.

There are various methods that have been used for clamping and lifting a pipe. Some of them are explained below.

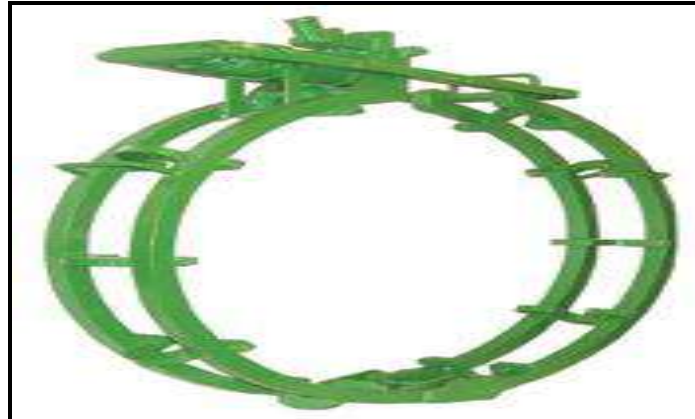
#### 1.1.1. Lifting clamps



**Fig.2 Lifting clamp [10]**

Lifting clamps are simple machines. Most lifting clamps use sharp teeth to bite into the surface of the component being lifted. Once a clamp has bitten into the surface, it effectively becomes one with the surface and therefore the component can be safely lifted. The design of the clamp is such that the load applied to the hook ring is magnified through a system of links to give a high gripping force to push the jaw teeth into the lifted component. This gripping force is directly proportional to the load applied and self actuating (i.e. the higher the load applied, the higher the gripping force). This is known as the primary action. A secondary force generated by movement in the lifted component supplements the primary gripping force, if the plate starts to slip from the clamp, the moving jaw is turned with the surface and the cam shape of the jaw increases the gripping force.

### 1.1.2. Hydraulic cage clamp

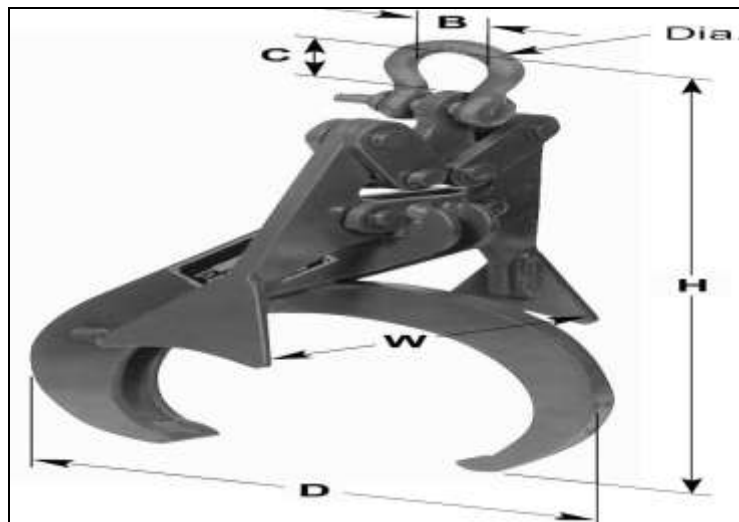


**Fig.3 Hydraulic cage clamp [11]**

The Hydraulic Cage Clamp consists of a right frame, left frame, latching mechanism and hydraulic bottle jack. The Hydraulic bottle jack consists of a reservoir, pump, on and off valve, machined piston and cylinder with adjustable extension screw. The hydraulic jack is rated at 12 tons. The Cage Clamp is used for the alignment pipes 16" to 60" in diameter. The clamp is designed to align only one diameter of pipe.

### 1.1.3. Pipe Grab

Automatically clamps to pipe when lowered onto it. Moveable outriggers stabilize the pipe during lift. No blocking required. Quick and efficient handling of properly balanced pipe.



**Fig. 4 Pipe Grab [12]**

### 1.1.4. Pipe Tongs (PTL)

Pipe Tongs are made of sturdy construction to handle pipe, round bars, castings, etc. Tongs are provided with bare steel curved gripping arms. Optional replaceable urethane pads are available to protect smooth or polished surfaces. Load must be balanced and controlled when lifting. May be used in pairs with a lifting beam for added stability.



Fig. 5 Pipe Tongs (PTL)[12]

### 1.1.5 Stewart platform-based concrete pipe manipulator (SPPM)

Stewart platform-based concrete pipe manipulator was developed by Stewart, the Korea Institute of Construction Technology (KICT), in order to resolve problems related to conventional concrete pipe installing work in trenches. In developing the SPPM, this study first conducted a needs analysis for automation using a cost-concern matrix.

The resulting SPPM is mounted on a Stewart platform that is capable of 6 degree-of freedom (DOF) movement required for automation of this work. The SPPM consists of the following four major parts:

- 1) A connection part to allow easy connection with the crane.
- 2) Stewart platform to support 6DOF maneuver for pipe installation.
- 3) A clamshell-type hydraulic clamping device to lift and move heavy-weight concrete pipes to the installation position, as well as for steady handling of the pipes; and
- 4) Sliding system for insertion to connect the next pipe to the previously installed pipe.

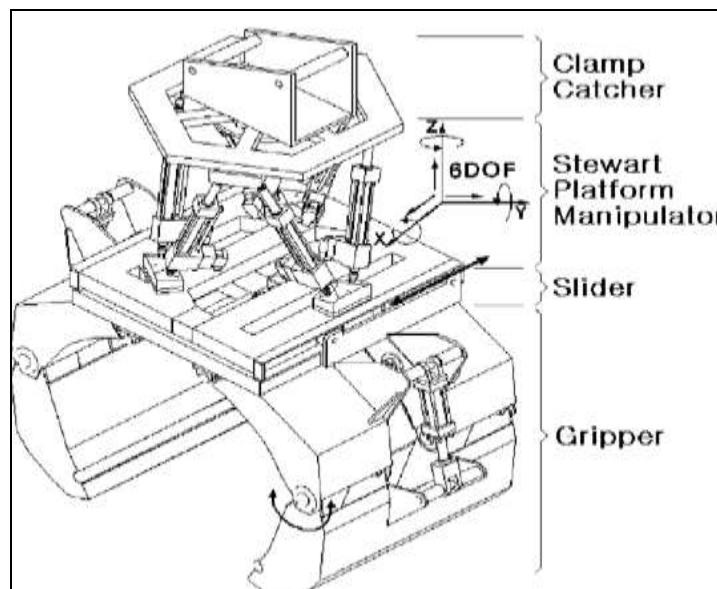


Fig.6 Major Hardware components of the SPPM[3]

Specially-designed connecting unit, (as shown in Fig.6.) allows the independent SPPM to be connected to a crane. A servo system is installed and pressure reducers are used to supply appropriate fluid. The position and status of the SPPM are sensed by the servo system and potentiometers. A Global Positioning System (GPS) receiver is also installed to collect real-time positioning data in order to generate drawings after completion of the work. To provide visual feedback to the operator, two cameras are installed in the middle of the SPPM and are aimed at the connecting part between pipes with a 45° angle viewpoint. The Stewart Platform mechanism, a 6 Degree-of-Freedom (DOF) parallel robot system, lends the SPPM roll, pitch, and yaw actuation. The device is

designed with a maximum open width of 1200mm, and thus the clamp can grip and handle a concrete pipe of up to 1200 mm diameter. The clamshell-type clamping device is end-effectors of the manipulator, which easily grips and releases the pipes. An electro-hydraulic system is applied for control and is powered by the crane.

#### 1.1.6. Two DOF hydraulic pipe manipulator (Pipeman)

The Pipe-manipulator developed at the North Carolina State University (NCSU) uses a serial mechanism with 2-Degrees of Freedom (DOF) [2]. NCSU simplified the equipment by letting the equipment perform only a linear motion along the x axis and on rotational motion around the z axis while the crane provides the other three DOFs.

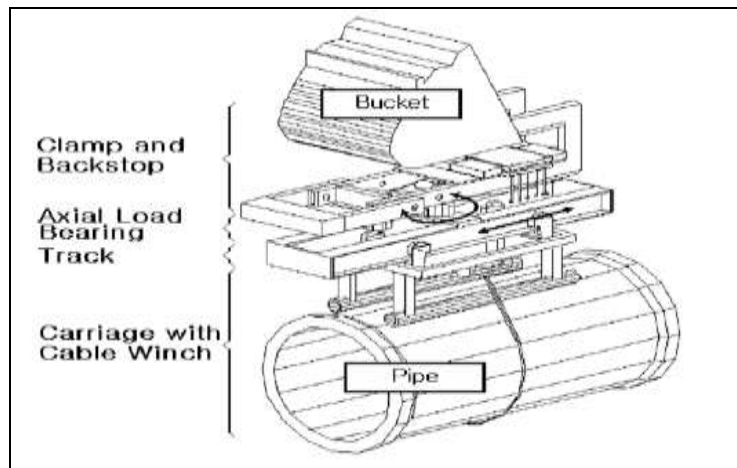


Fig.7 Two DOF Pipe Manipulator [3]

The System (see Fig.7) consists of four main elements:

- 1) Mechanical connector to the crane excavator,
- 2) System for aligning the pipes in the proper line and grade,
- 3) Mechanism for jointing two pipes, and
- 4) Means for handling one pipe segment.

The Pipeman was designed to attach itself to the bucket of the crane excavator involved in trenching without the need for a special tool-changing mechanism. For this reason a C-clamp-type fastening approach was chosen. As shown in Fig.7, two solid-steel brackets provide an opening for the operator to insert the front edge of the bucket. A mechanical backstop, ready for operation after the hydraulic lines are connected to the actuator, prohibits the bucket from sliding off. The clamping force is provided by a heavy-duty hydraulic fluid bladder located underneath the bucket. By opening the hydraulic valve, hydraulic fluid fills the bladder until the maximum pressure is reached. Emptying the bladder after use depends on the backhoe forcing the fluid back into the return line. As discovered during the field experiments, this is not a very efficient method because this requires some time during which the excavator is not able to do productive work.

## II. Literature Review

Rad and Kalivitis [2011] [1] described various stages of design and development of a low cost sensor-based gripper. Grippers are useful for applying right gripping forces to different objects. The gripper was also equipped with range sensors in order to avoid collisions of the gripper with objects. It was a fully functional automated pick and place gripper which can be used in many industrial applications

Kim and Bernold [2008] [2] compared the two innovative technologies for safe pipe installation. In that authors discussed about the conventional method of pipe installing and Stewart Platform based Pipe Manipulator (SPPM). The SPPM was built with sufficient DOF to manipulate a pipe accurately but its motion control interface is hard for operators to learn. The quality of the finished work is influenced by the experience and skill of the operator of the backhoe excavator, pipe installers and helpers. Authors compared the two approaches and technical solutions.

Kim et al. [2009] [3] carried out work on a performance evaluation of a Stewart platform based Hume concrete pipe manipulator (HCPM). Authors identified the problems in conventional process of Hume concrete pipe laying work. HCPM was developed to improve the safety, quality, and productivity of conventional Hume concrete pipe laying work. Authors developed a model for performance evaluation of the HCPM, and then utilize the model to analyze the HCPM's overall work performance.



Alexander et al.[2003] [4] invented concrete pipe lifting jaw. Authors proposed design of jaw system for multiple size pipes. The main objective of this research was to provide pipe lifting apparatus and method suitable for use on various ranges of concrete pipe sizes.

Francois et al. [1999] [5] designed a simple three-finger gripper. The gripper was designed to realize a good compromise between limited workspace and robust grasping. Authors carried out a complete analysis of the stability of a grasp for this gripper including an analysis of the deformation of the fingers at the points of contact. Presented results on three-dimensional representations of objects computed from range data.

Datta and Deb [2011] [6] proposed determination of optimum forces to be extracted on robot grippers on the surface of a grasped rigid object a matter to guarantee the stability of the grip without causing defect or damage to the grasped object. Authors proposed solving a multi criteria optimization of robot gripper design problem with two different configurations involving two conflicting objectives and a number of constraints.

Lanni and Ceccarelli [2009] [8], [2002] [9] proposed an optimum design of two-finger robot gripper mechanism using multi-objective formulation, considering the efficiency, dimension, acceleration and velocity of the grasping mechanisms and Presented a case study in the form of designing a gripper mechanism by using an 8R2P linkage. Numerical results have been reported to show the new proposed optimum design.

By all this literature survey it is concluded that, there are two basic systems available for concrete pipe handling i.e. with the use of crow bar and human worker and second is fully automated system. Therefore it needs to be design semi-automated system which reduces the cost of equipment and improves the worker safety.

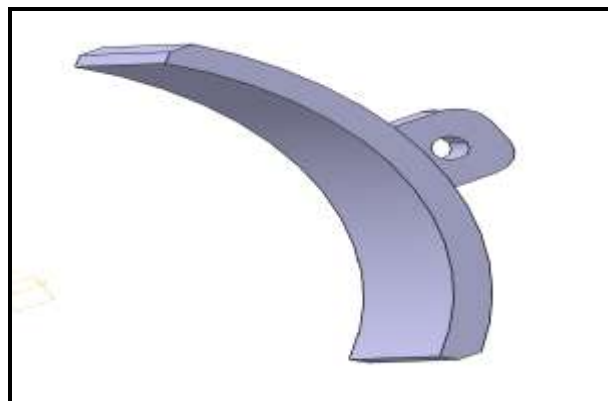
### **III. Auto-Gripping Jaw System for Concrete Pipe Handling**

The system of Auto-Gripping Jaw system for concrete pipe handling consist of a jaws coupled by chain mechanism to the crane hook. The pull in the chain mechanism is converted into clamping force between jaw and pipe by the clamping system. Lifting and placement of the concrete pipes can be managed safely by the concrete pipe handling system equipped by jaws. Light weight, structure is simple, so the usage of it is very favourable.This chapter discusses the modelling of all the components of auto gripping jaw system.

#### **3.1. Model of Jaw Set**

Auto gripping jaw system consists of four gripping jaws. So weight of the pipe andgripping force are equally divided to all jaws.

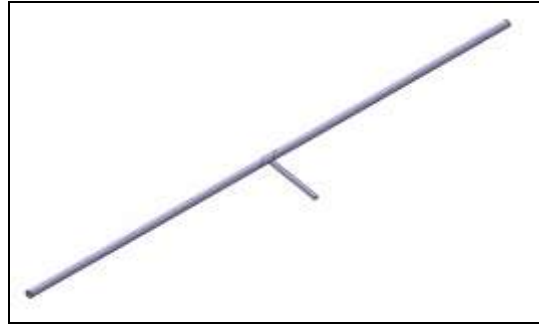
B. Model of Pin at JawPin in each jaw is subjected to direct shear stress at its cross-section and also compressive stress at its surface area due to gripping force and weight of pipe. Pin is placed at each jaw hence the gripping force is also divided atfour pins equally



**Fig.8 Jaw**

#### **3.2. Model of Torsion Rod**

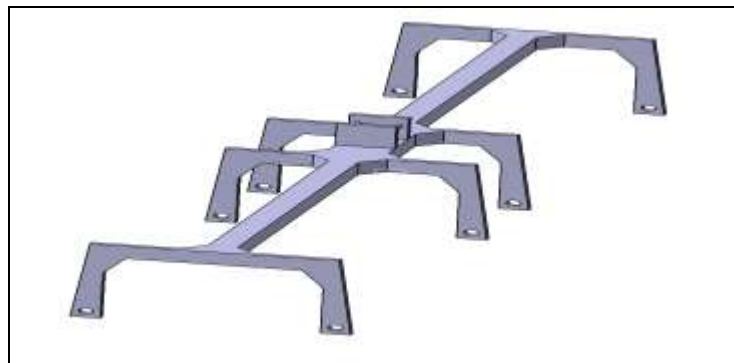
Torsion rod is subjected to torsion due to lifting force and bending moment due to weightof the pipe (W). The length of the pipe is 2000 mm. The jaws are to be placed on the pipeat some convenient distance of 1450 mm from each other. Hence, selecting the length of the torsion rod as 1450 mm.



**Fig.9 Torsion Rod**

### 3.3. Model of Frame

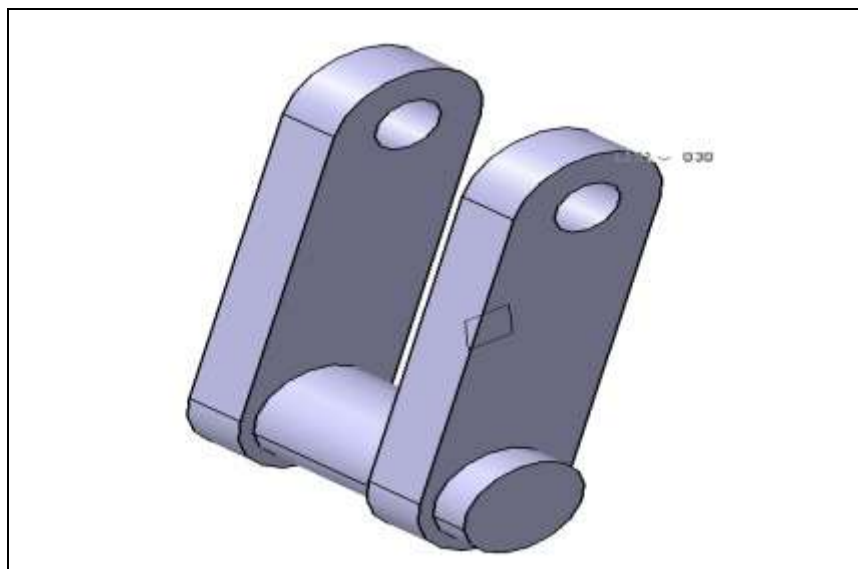
The frame consists of two parts. One is upper channel of rectangular cross-section and second is side member (as shown in Fig.10) of C shape which is also of rectangular cross- section. The upper channel is used to support the two side C shaped members. The height of C member is selected based on diameter of concrete pipe i.e. it should be greater than 102 mm. Hence height of C member is selected as 202 mm. And it has 20 mm diameter hole at the bottom to insert a torsion rod in it. Gripping force is evenly distributed to all members of frame.



**Fig. 10 Frame**

### 3.4. Model of Rotating Arm

Rotating arm connects the torsion rod to each jaw. The diameter of pipe is 204 mm. The maximum distance between two ends of C member of frame has been taken as 300 mm. Diameter of torsion rod is 20 mm and diameter of pin at jaw is 10 mm. Soby considering these all factors dimensions of rotating arm is arbitrary selected (as shown in Fig. 11).



**Fig.11 Rotating Arm**

### 3.5. Assembly of Auto-gripping jaw

The final assemble of Auto-gripping jaw is shown in fig. 12

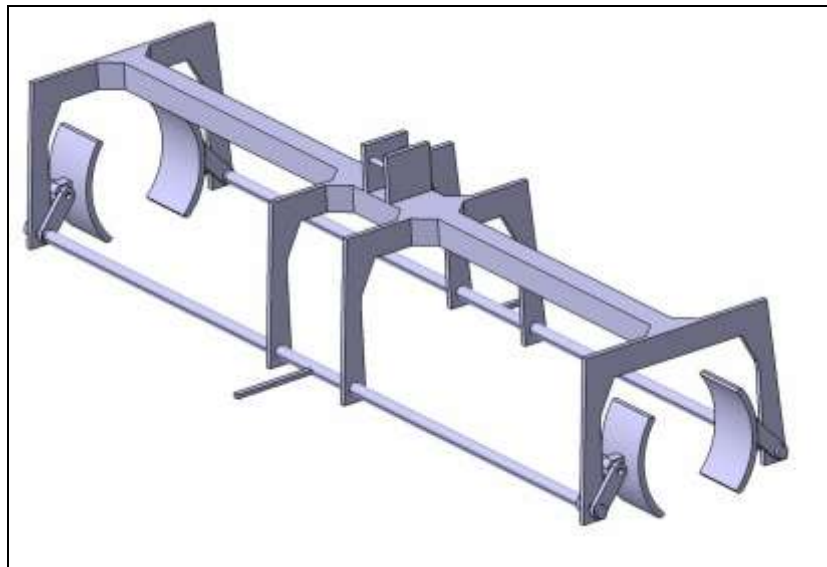


Fig.12 Assembly of Auto-gripping jaw

### IV. Conclusion

Auto-gripping jaw system for concrete pipe handling has been developed. The concrete pipe lifter system comprises of two jaws coupled by chain mechanism to the crane hook. The pull in the chain mechanism is converted into clamping force between jaws by the clamping system. Lifting and placement of the concrete pipes can be managed safely by the concrete pipe lifter equipped by jaws. Light weight, structure is simple, so the usage of it is very favourable. Auto-gripping jaw provides an intermediate solution between conventional methods and highly automated methods. It is very useful in various regions of country where highly automated systems cannot be used.

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