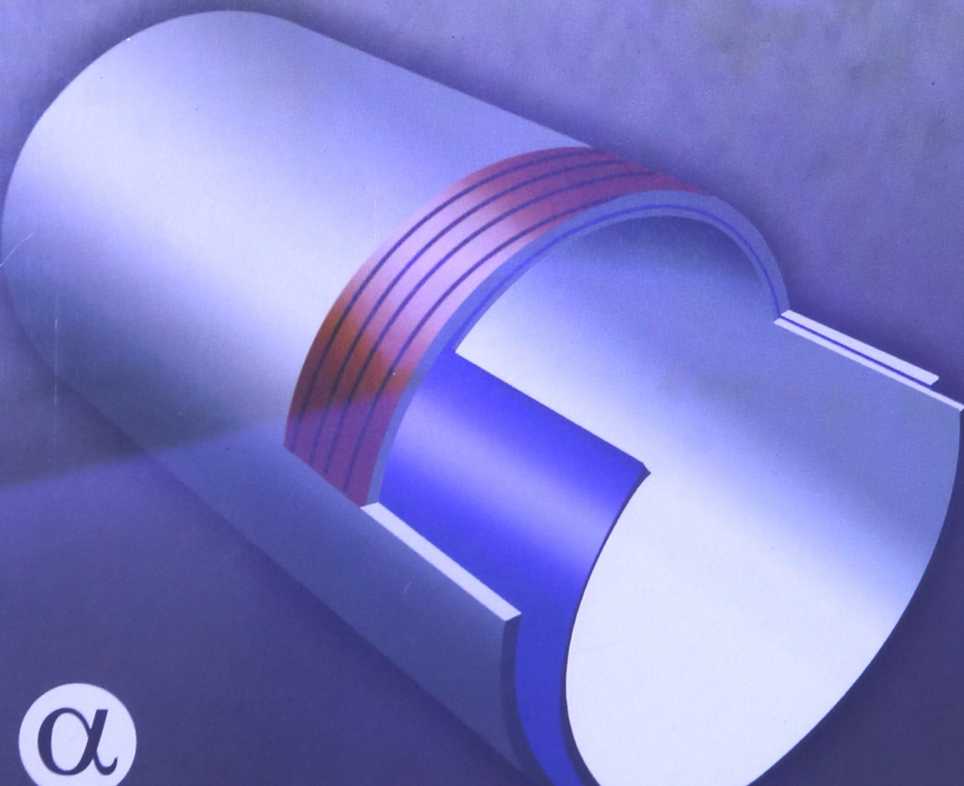
# Prestressed Concrete Pipes and Pipelines

N.G. Joshi



Alpha Science

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**N.G. Joshi**



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*Late Shri Bahubali Gulabchand, Chairman and Managing Director*
*Shri Arvind R. Doshi, Joint Managing Director*
*Late Shri V. P. Limaye, Chief Engineer*
*The Management, Technicians & Workers of*
THE INDIAN HUME PIPE CO. LTD.

**By N.G. Joshi**

# Preface

The pipelines are being constructed in ever increasing diameters, lengths and working pressures. Accurate and rationalized design basis are essential to achieve economical and safe design. Engineers have for many years, resorted to semi-imperial design formulae. Much work has recently been done, in an effort to rationalize the design of pipeline. PSC Pipe is comparatively new in this field, hence there is more need to provide latest information both for design and for manufacturing.

The book presents the information collected during visits to various plants in advanced countries like France, Germany, Japan, etc. and discussions with the experts in the field. Although retaining conventional approaches in many instances, the aim of the book is to bring the most modern design and manufacturing techniques to Civil, Hydraulic and Production Engineers, who prepare Water Supply Projects and who use the pipeline and maintain it. Because of the sound theoretical background, the book will also be useful to undergraduate and postgraduate students. Many of the subjects such as standard bedding, stresses in coating are still in their infancy and the book may provide lead for further research.

Spinning technique has been discussed in more details so that it will be useful to manufactures of RCC pipes and Piles also. Manufacturing problems and solutions are covered for the benefit of production personnel. Laying, bedding and design of rubber rings is included; rarely found elsewhere.

Numerous illustrative examples are given everywhere, hence it is expected that it will be useful to practicing Engineers in Water Supply Projects.

**N.G. Joshi**

# Acknowledgements

The basics of this book are derived from my experience in the course of duties as Chief Engineer in The Indian Hume Pipe Co. Ltd., My thanks are also to Mr. Carril of Boona Spain, Mr Hiroshi Satoh of Nippon Hume Pipe Co. Ltd., Japan, Dr. D. Kittle of Dyckerhoff & Widmann, Germany, Mr. Gunter Mundel of Zublin, Germany, who without any reservation, allowed me to visit their factories where latest technology was used. My special thanks are to Mr. P.D. Kelkar of The Indian Hume Pipe Co.Ltd., with whom I had prolonged discussions on many items mentioned in the book and whose frank opinion is always welcome. Thanks are also due to Mr. Pillai of The Indian Hume Pipe Co. Ltd., (who is no more), who conducted the experimental work. Mr. A.C. Patil, Engineer, and Mr. A. Ramchandran of The Indian Hume Pipe Co. Ltd., who prepared the draft, deserves special thanks.

The extensive knowledge I collected, is because of co-operation given by every member of the organization and the encouragement by the Management, which is reflected in the book.

**N.G. Joshi**

# Contents

# Chapter 1

# Short History of Concrete Pipes

## 1.1 INTRODUCTION

With development of civilization, man felt the need of pipe, for fetching fresh water and discharging polluted water. Early pipe lines (conduits) were cast in situ, made of either burnt bricks, lime concrete or stone. Subsequently pre-cast pipes made of burnt clay, wood and concrete came into use. The oldest pipe is said to be Roman water line; constructed around 800 B.C. The water carried by these conduits was used primarily for drinking purpose, and to carry sewage through Rome's main sewer – the CLOACA Maxima. The oldest recorded concrete pipe sewer installation was in 1842 at Mohawk, New York.

In $19^{th}$ century public became conscious of the need of civic amenities such as water and drainage. Demand for pipes thus increased and that gave fillip to the development of pre-cast concrete pipes. Growth of concrete pipe has been spectacular since 1930. Following the depression years of world war II, annual production doubled to 4 million tons by 1950 over the globe.

## 1.2 PIPE MATERIALS - EARLY DAYS

In India cast iron pipes used during the early British period, were mostly imported. Indian Iron Ltd. at Kulti started manufacturing vertical cast iron pipes, upto 48" (1200 mm) diameter in 1900. They started making cast iron spun pipes, upto 30" (900 mm) diameter, from 1947 onwards. The first pre-cast concrete pipe by spinning process (Compaction by Centrifugal Force) was made in India around 1918-1920 at Calcutta, by an European firm. Due to various reasons, this concern was closed in few years. The Indian Hume Pipe Co. Ltd. formed in 1926, started producing concrete pipes by spinning process, on a commercial scale.

The first steel pipe was made in India around 1932, by The Indian Hume Pipe Co. Ltd. called HUME STEEL PIPE i.e. steel pipe with lining and coating of concrete. The first prestressed concrete pipe was made around 1955, also by same company. Thus, The Indian Hume Pipe Co. Ltd. appears to be pioneer in pipe industry in India.

## 1.3 PIPE DESIGN AND DEVELOPMENTS

The main function of a pipe is to carry water, either under pressure or by gravity. In doing so, it is preferably laid underground and subjected to many movements such as differential settlement, extension, shortening etc. and to moving loads above ground. In the early days, some of the above factors were unknown and hence not considered. A pipeline now is considered to be a structural member subjected to various forces during its life span. A buried pipeline is now recognised as a load bearing structure and designed with growing confidence. Developments in Hydraulics, Metallurgy, soil mechanics, structural design and concrete technology, helped considerably towards improved pipe design. A rubber ring, flexible joint, was introduced to account for differential movements in soil.

## 1.4 SHAPE OF PIPE

The shape of pipe is so selected, as to effect economy in material cost and to ensure better hydraulic efficiency. A circle has the least perimeter for the area enclosed; hence pipe is circular in cross-section.

## 1.5 PIPELINE MATERIALS OF TODAY

Materials technology has evolved the most, among all aspects of pipeline engineering, in the last 30 - 40 years. Many new materials and products appeared in the market, and an equal number of products, and trade names, disappeared.

The Concrete pipe Industry in America, Europe and Asia has seen numerous developments in the manufacturing processes, automation and use of robotics. Some Nordic countries and West Germany have introduced admixture such as Micro Silica in concrete pipe construction, for better strengths and sulphide corrosion resistances.

The plastic pipe industry brought numerous developments to the consumer. Plastic competed extremely well against cast iron clay pipe, in small sizes initially. Having displaced clay from a good portion of small size market began to increase its bore sizes to be able to capature the market shared by concrete and other pipe materials. By middle eighties, the stiffness of large diameter plastic pipes dropped to a level requiring special installation and handling techniques, which were new. Contractors had trouble for installing these low stiffness products. When field performance fell short of requirements set by consumers, claims were filed against all parties. Most plastic pipe developments originated in Europe and were tried initially in European market. Having felt too much resistance in Europe from the consumer and traditional material such as concrete and clay, eventually found their market nitche predominately in United States.

Composites (pipes made of composite materials) have also gained considerable momentum over the years using primarily glass fibre. The early pipe products made in U.S.A with sand matrix suffered significantly due to poor quality control, inadequate design procedures and longitudinal stress, disappeared from the market place, in a cloud of litigation, briefly in mid eighties.

## 1.6 ENTRY OF CONCRETE INTO PIPE INDUSTRY

Concrete became popular in latter part of 19$^{th}$ century, because of its compressive strength, durability etc. but its use for pipe making was not considered feasible; because concrete was considered unsuitable for tensile stress, whereas in pipe wall the stress is mainly tensile.

Invention of spinning process made it possible to withstand the tensile stress in pipe wall. This special property of spun concrete was first realised in Germany in 1907 and used for making poles. In U.S.A. spun concrete poles were made in 1931 and around 1920 in Italy. All these used spinning process for making poles but in 1910, walter Humes of Australia, developed an efficient spinning process for making pipes of different diameters. In India, it is used since 1926, after the Indian Hume Pipe Company Ltd obtained its patent rights.

## 1.7 DEVELOPMENT OF CONCRETE PRESSURE PIPE (as originally advocated by Walter Humes)

Basis of design of concrete pipes has been to limit the tensile stress in pipe wall to a safe figure i.e. limiting factor in design has been the tension in concrete. Tension at test pressure is limited to 350 to 400 psi (24.60 to 28.12 kg/cm$^2$). The area of circumferential steel is calculated by dividing the tension in the pipe wall by 1600 psi (112 kg/cm$^2$). This method has been validated by some 50 – 100 years of use in hundreds of RCC Pipes, in all sorts of conditions, over the globe.

Concrete pipe is now technically classified as rigid pipe, because its deflection under external loads is negligible. Use of reinforcement made it suitable for pressure pipes, up to pressure of 6 kg/cm$^2$. This rigid character has many advantages and is one of the main reason for its retention in market even after 100 years.

## Pressure Pipeline Designs

Pressure pipeline designs received considerable attention during the past 50 years from all the segments of industry. Now a days the pipes are grouped as rigid, semi-rigid and flexible. The rigid pipe is designed, by comparing its load carrying capacity in the installed condition to the load applied, to ensure that the pipe does not fail in flexural tension. The manufacturers in Europe and Asia use thinner walls particularly in large diameters than their counterparts in USA. **Further development of R.C.C. pipe is the prestressed concrete pipe, which soon became popular, as pressure pipe.**

## 1.8 SUPREMACY OF CONCRETE PIPE

Even-though various materials have entered into the pipe industry, the concrete pipes have maintained its place both for non-pressure and pressure pipes. There is no other suitable pipe material today, than concrete pipes, for sewers. It has the added advantage of installation by "Trenchless Technology" which is also called "Pipe Jacking", a technology, by which pipeline installed underground, without the excavation of a trench; causing obstruction to traffic. This is a must in the present days of heavy traffic. Concrete pipe is the only pipe material by which pipe jacking is possible. With other pipe materials this is not possible. General arrangement for pipe jacking is in Fig. 1.

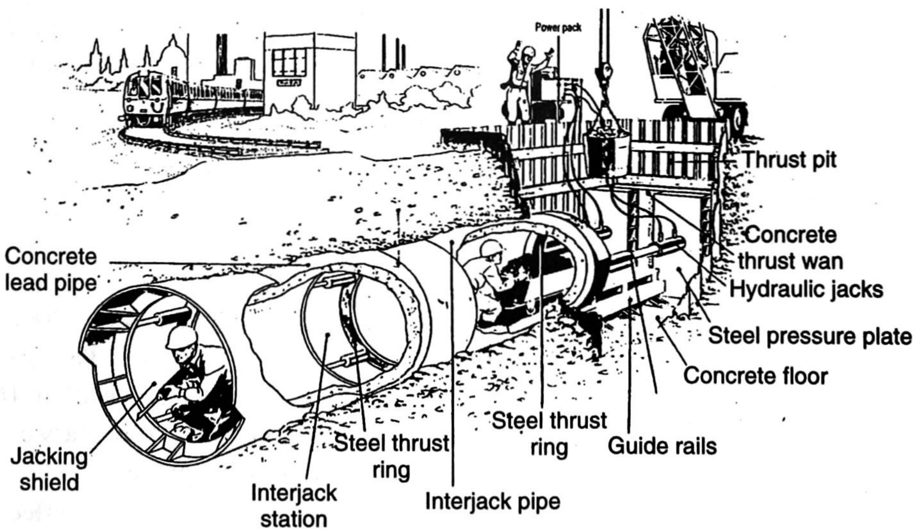
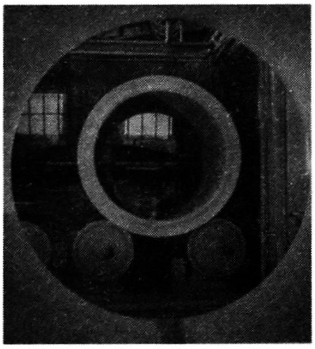



**Fig. 1** General arrangement for pipe jacking

Photograph 1 Walter Humes



Photograph 2 Spinning Machine

• THE HUME STORY. Melbourne – Humes Ltd., (1980) 9 p
• Pipe Jacking Association, A guide to pipe jacking Design London.5 p

# Chapter 2

# Background of Prestressed Concrete Pipes with Unique Properties

## 2.1 DEVELOPMENT OF PSC PIPES

Prestressed concrete pressure pipes have been developed to extend the scope of the reinforced concrete pipes with their advantages of economy and durability, into high pressure field. These pipes are ideally suited for the pressure range of 5 to 20 $kg/cm^2$. For this range cast iron and steel pipes are not economical and RCC pipes are not feasible.

Technique of prestressing was first applied successfully as early as 1930. However, further developments were severely hindered during the war. The first commercial application of steel cylinder prestressed concrete pipe was in the year 1942. Since then numerous pipelines have been installed throughout the world. During the same period, studies were undertaken on the economies of production of prestressed concrete pipe with all concrete core i.e., without steel cylinder. **By 1944, the first non-cylinder prestressed concrete pipeline was installed. Since then various techniques have been developed by different manufacturers.**

### 2.1.1 Fundamental Concept

When the pipe is subjected to internal pressure, a direct tensile stress is produced in the pipe wall. When this tension exceeds tensile strength of concrete, cracks are developed. If pipe is precompressed prior to use, internal water pressure during service would stretch the pipe enough to relieve the induced precompressive stresses and overcome the direct tensile strength of concrete before the concrete would crack.