**Required Reading:**
*Concrete Pipe Handbook*, Chapter 4 Loads and Supporting Strengths  
CP Insight - *Concrete or HDPE: Strength versus Stiffness*  
Design Data No. 1 - Highway Live Loads on Concrete Pipe  
Design Data No. 3 - Railroad Loads on Concrete Pipe  
Design Data No. 5 - Multiple Pipe Installation: Trench Condition  
Design Data No. 6 - Loads and Supporting Strengths Elliptical and Arch Pipe  
Design Data No. 7 - Transition Width  
Design Data No. 9 - Standard Installations & Bedding Factors for the Indirect Design Method  
New Installation Designs for Buried Concrete Pipe  
C.P. Info - *Lateral Pressure & Bedding Factors*

**Suggested Reading:**  
ASTM C 76  
ASTM C-506  
ASTM C-507

As a basic study of the design characteristics of RCP, this course is intended to provide an understanding of the how and why’s of RCP design rather than the in-depth technical details of designing a pipe. The opportunity to develop design skills will come in a later module. However, reading through the examples at the end of Chapter 4 in the Concrete Pipe Handbook to ensure an understanding of the concepts for this course, is expected. The focus for this course is the terminology, design theory, and history that support the fundamentals of current RCP design.

Again, this course is intended as a basic level of study, therefore some topics will not be covered in depth. The design concepts behind *airport loading*, while similar to highway loading require extensive knowledge regarding impact loads, wheel loading, and wheel load footprints. *Tunneling and jacked pipe* is another subject matter that requires a higher level of expertise to fully appreciate. For now, focus on the terminology regarding these subjects to prepare oneself for future learning.

Simply reading this summary will not prepare one to take the test for this course. This text is only intended to clarify some concepts and to highlight the areas that are considered important. This text purposely avoided displaying equations and formulas as they are covered in depth in the resource documents. As stated previously, terminology is important. To hold an intelligent conversation regarding the structural design and load
carrying aspects of RCP, one must understand the key phrases that are bold and italicized. Some of these phrases appear throughout this summary while others are at the end of this summary.

Do not hesitate asking for help if you are confused or stuck on a topic. Gaining a thorough understanding of the material is the key to success. Good luck on your studies.

**RCP Strength: Major Concept**
The structural design of RCP is the main factor in the load carrying capacity of a pipe. RCP is designed, manufactured, tested, and installed as a rigid structure with a minimal portion of the loads present supported by the surrounding soil. The majority of the load is distributed too and supported by the pipe.

**LOADS**
Determining the required supporting strength of RCP is dependent on the total load imposed on the pipe.

There are three types of loads that are considered:

- **Earth load** is the weight of the earth that must be carried by the pipe. The amount of earth load carried by the pipe is determined by the soil characteristics and the installation conditions.
- **Live loads** are the loads transferred through the soil to the pipe by vehicular traffic (more specifically, truck traffic), planes, and trains. The footprint of the vehicle greatly affects the load transferred to the pipe.
- **Surcharge loads** are typically loads from buildings or additional earth fill.

When determining the fill height under pavement sections it is important to know from what locations the measurements are made. Using AASHTO guidelines, the location of measurement varies by the type of pavement section. Under a rigid (concrete) pavement section, the measurement is made from the outside top of the pipe to the bottom of the pavement section. Under a flexible (asphalt) pavement section, the measurement is made from the outside top of the pipe to the top of the pavement section.

**Determining Earth Loads**

**Installation Conditions**
A rudimentary understanding of the types of installation conditions is required to gain an understanding of how earth load is transferred to a pipe and why different installation conditions allow for more or less load to be placed on the pipe. A trench type installation reduces the load carried by the pipe while in an embankment situation the pipe carries the entire earth load.

**Trench** pipelines are placed below grade in natural ground with relatively narrow excavations and the pipeline is covered with earth backfill up to the natural ground level.
A trench installation allows for the frictional forces developed between the trench wall and the backfill material to reduce the load that the pipe must carry.

**Embankment** pipelines are placed at grade and covered by a constructed embankment. An embankment condition exists when there is no supporting trench wall or existing soil to induce frictional forces upon the backfill material as it settles to reduce the load applied to the pipe. There are three subsets of an embankment condition. The subsets are:

- **Positive projection** is a situation when the pipe is initially placed; the top of the pipe is above grade. This situation can also occur in wide trenches.
- **Negative projection** occurs when the pipe is initially placed in a shallow trench, whereas the top of the pipe is below grade and the pipe is then covered with fill to a height appreciably greater than the distance from original grade to the top of the pipe.
- **Induced trench** is an attempt to reduce the loads transferred to a pipe in an embankment situation. The pipe is originally installed in a positive projection situation and backfilled to a height of at least one pipe diameter above the top of the pipe. A trench is then excavated over the top of the pipe and backfilled with a loose compressible material. As additional fill is placed, the more compressible material allows for transference of the loads to the more densely compacted fill on each side of the pipe.

**Multiple Pipe Installations**
Having two or more pipes placed in a single trench or in an embankment situation is quite common. The placement may be in a flat trench (side-by-side) or in a benched trench (vertically separated) situation. The critical factor with both situations is determining whether the pipe is being exposed to trench or embankment loading conditions.

**Determining Live Loads**
The basic equations for determining load distribution through earth masses were developed in the mid-nineteenth century by Boussinesq. These equations are based on the theory of elasticity. The subsequent calculations to determine live loads can be quite cumbersome. Fortunately, AASHTO has approved a method to eliminate some of the more difficult steps. AASHTO presents highway wheel load configurations and contact pressure areas that are normally considered for design purposes for truck traffic. Given this information, it is then possible to calculate the average pressure intensity at the outside top of the pipe, the total live load that the pipe is exposed to, and the live load per linear foot of pipe. Determining live load from Cooper E 80 loading is made even simpler by the development of a chart as shown in the Concrete Pipe Handbook. This is a short summary of live loads and is far from a complete discussion. Considerable study will be required to be able to understand the theory behind live load distribution, much less to perform a calculation.

**SUPPORTING STRENGTH OF CONCRETE PIPE**
Determining the supporting strength of the pipe is dependent on the structural strength of the pipe and the type of bedding designated for a particular pipeline. Type of bedding includes the type of fill material specified under and adjacent to the pipe, and the compaction of this fill material. Each of these key factors must be evaluated to determine the load carrying capacity of the pipe.

**Strength Testing Pipe**
The *three-edge bearing test* is commonly used to determine the strength of the pipe. This test method represents the most severe loading conditions that the pipe can be subjected too. The loads applied are virtually point loads and the pipe is provided with no lateral support.

**Bedding**
Spangler developed the original four classes of bedding. These were later changed to *Class A Bedding, Class B Bedding, Class C Bedding,* and *Class C Bedding.* These classification of beddings were detailed for trench and embankment situations for round and arch pipe. Each of these different classes of bedding has different correlating bedding factors. The bedding factor is defined as the ratio between the supporting strength of buried pipe to the strength determined by the three-edge bearing test.

**Safety factor**
The manner in which safety factors are employed in the design of RCP is a key concept in understanding the inherent strength of the pipe and the ability to design for a variety of applications and loading conditions.

**STANDARD INSTALLATIONS AND THE INDIRECT DESIGN METHOD**
The most recent development regarding RCP and its load carrying capacity was the implementation of the *Standard Installations; Type 1, Type 2, Type 3, and Type 4.* The correlating bedding details establish terminology, bedding factors, and specific soil classifications that are different from the previous bedding classifications and are unique to RCP. The six-step *indirect design* procedure may be followed to determine the required class of RCP for a particular pipeline. Again, reading the example problems at the end of Chapter 4 in the Concrete Pipe Handbook will help to gain an understanding of the indirect design process.

**TERMS TO KNOW**
In addition to the terms indicated in the above text, it is highly recommended to be able to define the following words and phrases and have a clear understanding of their meaning in terms of application.

*Transition width*
*Settlement ratio*
*Prism load*
Interior prism
Exterior prism
Critical plane
Central bedding angle
HS20
Alternate loading
SPIDA
SIDD
Haunch
Lower Side
Bedding
Outer Bedding
Middle Bedding
$D_o$
$B_f$
Crown
Invert
PIPECAR
VAF
HAF
Soil-structure interaction
Direct design
Wall thickness
Class I, II, III, IV, AND V Pipe
Compressive strength
D-load
Springline