



Design of Monorail Systems

An Online Continuing Education Course for Engineers

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Design of Monorail Systems

Tomas H Orihuela Jr, PE

Introduction

Overhead monorails are primarily used to lift large or heavy items and move them horizontally. Monorails can be driven manually or powered. Power-operated overhead monorails systems are typically powered by air, hydraulics, or electricity. Overhead material handling systems can be supported on single or multiple girders and can be top-running or bottom-running. Bottom-running systems travel along the bottom flange of the supporting beam and are typically associated with monorails and bridge cranes. Multiple girders and top-running systems are typically not associated with monorails but rather with overhead or gantry bridge cranes. This course covers the basic design of a monorail with a bottom-running manually-driven trolley hoist on a single girder or beam.

The course will first discuss how monorails can increase productivity and efficiency, reduce injury to individuals, produce cost savings, and even improve quality. Operation safety and inspection of monorails will also be discussed since the actual design calculation of a monorail beam is only a portion of a well-planned overhead material handling system.

The procedure presented for the design of a monorail beam is primarily based on the Crane Manufacturers Association of America (CMAA) Specification No. 74 "*Specifications for Top Running & Under Running Single Girder Electric Traveling Cranes Utilizing Under Running Trolley Hoist*". Fatigue checks and deflection limitations will also be discussed. Connections and supports will only be briefly discussed. An example of a basic monorail beam design is provided to assist in better understanding of the information presented in this course.

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Case Studies

Using monorails or other overhead material handling systems help increase productivity, efficiency, and safety while reducing costs and injury to personnel. Cases studies have shown that the use of such systems can do all of these things. Two case studies are presented below.

Case Study #1:

A company was showing an increase in employees with back injuries. Morale was low and insurance rates were increasing. Additionally, quality was an issue since 150 to 250-pound rolls requiring replacement 4 to 5 times daily were being dropped frequently by the two individuals performing the task. The addition of an overhead material handling system improved quality since rolls were no longer dropped during the replacement process, back injury to personnel was greatly reduced since lifting of heavy objects was eliminated, and, lastly, cost savings and increase in productivity were noted since the replacement process no longer required two individuals and took less time to perform.

Case Study #2:

A manufacturer of large and heavy mirrors had individuals injured often during the packaging process. Injury to personnel was occurring during the tilting and setting of the mirrors in shipping crates or when mirrors were dropped during this process. The packaging process took four individuals to complete the task. By installing an overhead material handling system, manually lifting the mirrors was no longer required, with reduced injuries. Improvement in cost savings, efficiency, and production occurred since less damage to or dropping of mirrors occurred and now only two individuals were required for the packaging task.

The two case studies presented show that overhead material handling systems could help reduce costs and injury while providing improvements in production, efficiency, and cost savings. One point to consider is insurance costs; with less individuals getting injured, the rising cost of insurance may be partially controlled. The case studies mentioned are summarized from studies found at various websites.^{4,5,6} The referenced websites provide various additional case studies showing similar results after the addition of an overhead material handling system.

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Operation Safety

The safe operation of a monorail has some impact to the design of a monorail system. Engineers need to be concerned with the operational safety of the monorails they design. To that end, engineering drawings should include some or all of the items listed below:

- maximum lift design load
- safety, impact, or load factors used
- maximum angle or load due to side pull
- method and locations of labeling stating maximum capacity, warnings, etc.

Additionally, the engineer needs to have a full understanding of how the final monorail system is anticipated to be operated. Without operations input, a monorail can be poorly designed for the intended use, ultimately resulting in the death or injury of the operator and/or bystanders.

A safety plan for the operation of the monorail should be developed with input from all parties involved: owner/specifier, engineer, inspector, and operator. The plan should incorporate, at a minimum, the following information:

- Responsibility of all parties
- Design requirements (i.e., codes, safety or impact factors, labeling, etc.)
- General safety rules
- Operational rules or instructions
- Rigging requirements
- Inspections, Maintenance, and Testing
- Record keeping responsibilities

The Department of the Interior's Safety Management Information System has a website that provides a written example of a crane and hoist operational safety plan.⁷ To assist in the development of a safety plan, this sample plan can be downloaded and is provided in a format that can be easily modified.

Operators also need to be properly trained to safely operate the monorail system. The following are methods that can be implemented to help ensure safe operation of the monorail:

- Proper training of operators and individuals in the area of use
- Use of check lists for inspection
- Scheduling of inspection (Interval based on level of use)
- Clear, unobstructed labels stating rated load on monorail beam and hoists

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The Hoist Manufacturers Institute (HMI) has created recommended practices for manual and powered hoists.⁸ The recommended practices list “Shall’s and Shall Not’s” for the operation of hoists. The documents provide valuable information and will assist in the development of an operational safety plan. A few of the items included in the recommended practices from HMI are listed below.

To avoid a potentially hazardous situation that could result in serious injury or death, the operator:

- SHALL NOT lift loads more than the rated load.
- SHALL NOT lift individuals if the systems is not rated for lifting of personnel
- SHALL NOT lift a load over people and SHALL assure other personnel stay clear of the load.
- SHALL be familiar with the operating controls, procedures, and warnings.

To avoid a potentially hazardous situation that could result in minor or moderate injury, the operator:

- SHALL avoid swinging the hook or load.
- SHALL inspect the hoist regularly
- SHALL NOT allow your attention to be diverted from operating the hoist.
- SHALL be familiar with the operating controls, procedures, and warnings.

Pre-planning

Remember the “Six ‘P’ principle”: Prior planning prevents pretty poor performance. Identifying all, or as many of, the design parameters in the initial stages of design allows for a better designed and operational system.

Some basic initial information and design criteria needed for the design of a monorail system includes:

- Design load rating or lift load
- Safety, load, or impact factors to use
- Design codes or other specifications
- Minimum clearances required
- Special requirements specific to the project
- Minimum or Maximum hook height
- Path of monorail
- Preferred method of support
- Connection types: welded or bolted
- Understanding of final use

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Part of the pre-planning process is to determine the classification of the monorail, which is required for the fatigue design check of the monorail system.

Monorail Classification

The classification of the monorail is mainly required for checking fatigue. CMAA Specification No. 74 has four (4) classifications that are based on the level of service of the system.

The classifications are:

- N_1 – intermittent use in intermittent operations – load during
- N_2 – intermittent use in intermittent operations – load and is
- N_3 – regular use in intermittent operations – lift.
- N_4 – regular use in continuous operations – 2,000,000 cycles per hour

In many cases, the monorail is used for intermittent operations. The code also provides detailed information on the classification of the monorail.

The four classifications are:

- N_1 – intermittent use in intermittent operations – load.
- N_2 – intermittent use in intermittent operations – load.
- N_3 – regular use in intermittent operations – load.
- N_4 – regular use in continuous operations – load.

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- N_4 – regular use in continuous operations – load.

How the classification of the system is used for fatigue checks will be covered later in this course.