CHARACTERISTICS OF MATERIALS USED IN CAVE AND MINE GATES

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Abstract

Function and cost are important factors when selecting materials for constructing cave and mine closures. Characteristics of common construction materials, special materials for increased security, and common finishes are factors in the design and planning process. Evaluation of longevity criteria and assessment of site environmental factors are vital to project planning. For each material commonly used in cave and mine gates, there are beneficial as well as disadvantageous characteristics—stainless steels, Manganal™, mild structural steels, concrete, aluminum, galvanized steel, plastic products, security inserts, paint, and other finishes. Specific knowledge about bat habitat and general common sense must dictate design and material selection. Although many materials can offer enhanced protection, often the most cost-efficient and readily available material that provides reasonable life expectancy for cave and mine gates is standard structural steel.

Introduction

What materials are safe and cost-effective for long-term use in the harsh environments of caves and mines? Characteristics of common construction materials are described in this paper. Emphasis is placed on materials that are considered corrosion resistant, tough, and readily available. Other exotic materials, though their characteristics may be beneficial to the protection of underground habitats, tend to be expensive, less available, and sometimes require special installation procedures. Typically, gates for caves and mines are constructed of structural steels, concrete, Manganal™, or stainless steels. In addition to gates, there are cave and mine closure designs that call for cable netting or chain-link—these materials are described in other papers included in the proceedings for the 2002 Bat Gate Design Forum.

Before planning and designing gate structures, you should evaluate the material options and fabrication requirements. Gate-builders should add several useful reference manuals to their libraries: *Machinery's Handbook* (Industrial Press); Manual *of Steel Construction* (American Institute of Steel Construction, Inc.); Electrode *Pocket Guide* (Airco); and *Ryerson Steels Stock List and Data Book* and *Ryerson Special Metals Data Book* (Joseph T. Ryerson and Son, Inc.). Materials reference books are updated regularly and contain useful information for any construction project. For example, the *Machinery Handbook* has sections on types and properties of materials, welding specifications, and finishes. The strength of materials section in the *Machinery Handbook*, has simplified mathematical formulas to use in calculating material strengths for gate designs.

Stainless Steels

Chromium-nickel austenitic steels are commonly known as stainless steels. Both names refer to the same family of steel materials. The corrosion resistance and toughness of stainless steels make them highly suitable for cave and mine gates. The longevity of stainless is ten-fold that of mild steels. However, since stainless is more costly than other gating materials, it is currently used only when required by special site circumstances or gate designs.

Stainless steel life expectancy and corrosion-resistance far exceed the characteristics of other materials. However, since vandalism is a key issue for cave and mine closures, and since replacing stainless is expensive, it may be more cost effective to choose other materials for gate construction. In extreme cases, where the environment is too harsh for mild steels to survive, the site conditions may dictate that stainless be selected for its increased life expectancy. Any of the chromium-nickel austenitic steels offer good characteristics for cave and mine installations, however, there are important fabrication requirements for these stainless steel materials.

There are a number of weldable chromium-nickel austenitic steels on the market. If the project is fabricated in a controlled, clean welding shop, any of the weldable austenitic stainless steels will work well. Find complete listings of the characteristics of austenitic steels in the *Machinery's Handbook*. For austenitic stainless steels, welding requirements call for shielded gas metal arc welding processes to minimize the potential for carbide precipitation, e.g., tungsten inert gas (TIG), or metal inert gas (MIG).

Generally, stainless cannot be properly fabricated in the field unless special welding equipment is used to purge the welds with argon to minimize corrosion-inducing carbide precipitation. If welding must be done in the field at the gating site, chromium-nickel austenitic steel types 304L, 316L, or 321 are recommended. These steels are less vulnerable to the harmful carbide precipitation that enhances weld corrosion (rust) tendencies.

For field applications, an optional method of construction may be to pre-drill and countersink holes in a fabrication shop, transport the pieces to the site, then use bolts to assemble the pieces. Holes for the rivet-like bolting can be drilled in the shop. After installing stainless steel bolts with countersunk heads, flatten the heads with a hammer, and then grind the nuts to a cylindrical shape so they will not accept a wrench.

Manganal ä

High-manganese, austenitic, work hardening steel that is currently used in some cave and mine gates is available under the trade name Manganal™. Typically, the chemical composition is manganese (12.00/14.00%) and carbon (1.00/1.25 %). Manganal™ bars, plates, and castings are used for high-impact industrial applications. Cost of high-manganese, austenitic, work hardening steel tends to run two to three times that of mild steel.

Manganal™ is used in extreme wear conditions and is hardened by impact, hammering, and abrasion. This surface characteristic is known as work hardening. In other steels (e.g., carburized or casehardened), the depth of hardness is fixed. When Manganal™ is subjected to wear, the surface toughens and the material remains ductile underneath.

Characteristics include high-strength, ductility, toughness, and substantial longevity. Corrosion resistance (e.g., rust and attack by acids) is about the same as ordinary steels. Manganal™ is extremely tough when work-hardened and may tolerate harsh environments. Functional mine rails made from this material are over 100 years old (Louis Arnodt, personal communication). Cave and mine gates constructed of Manganal™ can deter vandals using hacksaws, however power tools or cutting torches can breech the closures.

Continuous high temperature can cause high-manganese, austenitic steels to become brittle. In electric arc welding processes, no local area should remain at visible red heat for more than two or three minutes. If there is build up with multiple layers from weld passes, the welder may either skip weld, or weld intermittently to reduce localized heat.

Manganal™ is a good choice for field fabrication if the high cost is justified. Preferred applications tend to be in remote sites where minimal acidic conditions exist and where vandals cannot easily use power tools. Manganal™ is durable and has excellent longevity characteristics.

Structural Steels

The most common grade of structural steel (sometimes called mild steel) is ASTM A-36. The high-strength structural steels ASTM A-529 and A-440 have high carbon content for strength but they are no more durable than mild steels. Corrosion-resistant, high-strength steels have one advantage over the mild varieties in that they are more difficult to vandalize. Mild steels are easy to fabricate, readily available, and cost less than most other options. In some environments, the life expectancy is 50 to 100 years. Mild steel is available in a variety of structural shapes that are easily welded and fabricated in the field.

Aluminum

Aluminum will probably work for gates placed in dry, non-alkaline environments. However, aluminum is easy to vandalize because, generally, it is not as strong as steel. Aluminum can deteriorate rapidly and the degradation may introduce toxins into cave and mine habitats. For example, an aluminum ladder left in a cave located in the arid southwestern US literally deteriorated to a pile of scrap in less than 20 years (Werker, unpublished data). Aluminum carabineers left in caves for varying time intervals rapidly show signs of pitting and corrosive deterioration (Storage, 1994).

When aluminum structures are exposed to the atmosphere, a thin, invisible oxide skin forms immediately and protects the surface from additional oxidation. This self-protecting characteristic gives aluminum its high resistance to corrosion unless it is exposed to some substance or condition that destroys the oxide coating. Alkalis are among the few substances that will attack the oxide skin—thus, alkaline conditions will cause aluminum to corrode. When aluminum is placed in direct contact with other metals, the presence of an electrolyte (i.e., moist conditions or high humidity) will cause galvanic corrosion of the aluminum at the contact points.

Depending on the site conditions, protective coatings may increase the life expectancy of aluminum. Chromate coating can be brushed on in the field, but anodizing must be done at a coating lab.

Because aluminum is especially susceptible to both vandalism and corrosion, it is usually a less desirable material for cave and mine applications.

Concrete

Concrete works well in most environments. It is resistant to chemical and corrosive attack and has extremely good longevity characteristics. Structures built with 3000psi concrete reinforced with rebar will deter vandals and will hold up for many decades in most environments. Cement is made of clay and limestone—thus, concrete is likely to add few if any toxic materials to cave and mine systems.

Culvert and Pipe

Culverts and pipes used for cave and mine closures can be made from a variety of materials. Several material types are addressed below. Be aware that culverts or pipes may not be the best option for protecting most bat colonies. Small diameter flyways can set the stage for easy predation of bats.

Galvanized Steel

Galvanized steel culvert has been used in roadway construction for decades and seems to function well. However, in caves and mines, galvanized culvert may deteriorate rapidly. For example, a galvanized culvert installed in Lechuguilla Cave in 1986 showed visible signs of degradation by 1994 and had severely deteriorated by the time it was replaced in the year 2000 (Werker, unpublished data).

As the zinc coating of galvanized steel degrades, it may generate harmful by-products. Welding galvanized material results in noxious fumes that can be hazardous to human health. The breakdown, out-gassing, and deterioration of galvanized steel culvert introduces by-products that may be especially toxic to bats. The by-products of deteriorating galvanized steel may adversely affect other cave or mine-dwelling animals and plants.

Plastics

Little is known about the degradation processes of plastics used in cave and mine environments. Polyvinyl chloride (PVC) used in water lines and air conduits tends to become brittle over time. PVC also out-gasses potentially harmful substances. Until studies further define the longevity and degradation characteristics of PVC and various plastics when used in subterranean environments, other construction materials are preferred for cave and mine use.

Finishes

Finishes applied to the surfaces of materials, intended to enhance longevity, may add contamination to cave and mine environments. Many paints and finishes, over time, will deteriorate (sometimes flaking onto the habitat floor). Out-gassing of these products may introduce potentially toxic materials to underground cave and mine systems. Research is needed to investigate the potential benefits and harms of various finishes when used on cave and mine gates.

Common Sense

Investigating the multitude of material choices, evaluating their varying characteristics, and analyzing the cost, the potential for vandalism, and the inherent longevity of the materials can be an arduous task. First, evaluate the site, the habitat, and the purposes for the gate or soft closure. Simplify the goals, state the site objectives, and then allow common sense to dictate material choice and construction technique. In project planning, the priority is to be realistic about the habitat, the site requirements, and the budget.

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