MATERIAL PROPERTIES

Book 2

Designer's Den

Contents

Yield stress

Definition: Yielding stress, often denoted f_y, refers to the amount of stress that a material can withstand before it starts to deform permanently or exhibit plastic behavior. It is the stress at which a material undergoes a transition from elastic deformation (where it can return to its original shape when the load is removed) to plastic deformation (where permanent deformation occurs even after the load is removed).

Elastic vs. Plastic Deformation: In the elastic range, a material experiences temporary deformation in response to an applied stress but can recover its original shape when the stress is removed. However, once the yield stress is exceeded, the material enters the plastic range, and permanent deformation occurs.

Yield Point vs. Yield Strength: Some materials, particularly metals, exhibit a distinct yield point on their stress-strain curve, indicating the onset of plastic deformation. For these materials, the stress at the yield point is referred to as the yield strength. However, not all materials have a well-defined yield point, and in such cases, the yield stress is determined based on a specific criterion, such as a certain amount of strain or deviation from linearity in the stress-strain curve.

Importance in Design: Design engineers ensure that stresses on structural elements remain below yielding stress to sustain expected loads without undergoing excessive plastic deformation.

Steel
Steel is widely used in construction due to its high strength and durability. In Norway, steel used in structural applications typically adheres to the Eurocode design standards. The yielding stress of structural steel depends on its grade or strength class. Common steel grades include S235, S275, and S355, which correspond to minimum yield strengths of 235 MPa, 275 MPa, and 355 MPa, respectively. These values indicate the stress at which steel will begin to deform permanently.

Concrete
Concrete is a composite material composed of cement, aggregates, and water. Its strength and behavior depend on various factors, including the mix design, curing conditions, and reinforcement. In Norway, concrete design follows the Norwegian Standard NS-EN 1992-1-1 (Eurocode 2). The yielding stress of concrete is not as well-defined as in steel since it exhibits a gradual and nonlinear stress-strain behavior. However, the characteristic compressive strength of concrete is often used as a reference. Common characteristic compressive strengths range from 20 MPa to 60 MPa, depending on the concrete mix.

Timber
Timber, or wood, is a natural material used in construction, particularly in residential and low-rise buildings. The yielding stress of timber varies depending on the species, grade, and moisture content. In Norway, the most commonly used timber species include pine, spruce, and birch. The yielding stress of timber is determined through mechanical tests, such as bending or compression tests. As an example, structural softwood species like pine and spruce typically have yielding stresses ranging from 20 MPa to 50 MPa.

Material factors

Definition: Material factors, also known as safety factors or partial safety factors, are used in structural design to account for uncertainties and variations in material properties, loads, and other factors. These factors ensure that the designed structures have an appropriate level of safety and reliability.

Purpose: The primary purpose of material factors is to provide a safety margin by reducing the nominal or characteristic strength of a material to obtain a lower design strength. This accounts for uncertainties in material properties, manufacturing processes, environmental conditions, and other factors that can affect the performance and reliability of a structure.

Material-Specific Factors: Material factors can differ based on the type of material being used. For example, steel, concrete, timber, and other materials may have their own specific material factors determined through research, testing, and empirical data.

Design yielding stress: Design yielding stress refers to the maximum stress or load that a structural element or material is designed to safely withstand taken into account material factors.

Steel

In steel design, the material factor is denoted as γ (gamma). It is a dimensionless factor that is applied to the yield stress (f_y) of the steel to obtain the design yield stress (f_d). The design yield stress represents the maximum stress that the steel is allowed to experience under the design loads. The material factor accounts for uncertainties and variability in material properties, such as strength, manufacturing processes, and environmental factors.

For steel grade SXXX, which has a yielding stress (f_y) of XXX MPa, the material factor γ is commonly used to determine the design yield stress (f_d) as follows:

$$f_d = f_y / \gamma$$

The value of γ depends on the design standards and the specific application. In Eurocode design standards, such as Eurocode 3 (EN 1993-1-1) for steel structures, different material factors are assigned to different limit states (e.g., ultimate limit state, serviceability limit state). A common material factor γ is taken as 1.05

So for example steel grade S235 which corresponds to a steel type that have a minimum yielding stress of 235 MPa would have the following design yielding stress:

$$f_d = f_y / \gamma = 235 / 1.05$$

In steel design engineers would want to assure that the stresses in an element is less than f_d

Concrete

In concrete design, the material factor γ is also used to account for uncertainties and variations. It is used to determine the design characteristic strength of concrete (f_{cd}) from the characteristic compressive strength (f_{ck}) of concrete. The design characteristic strength represents the maximum stress that the concrete is allowed to experience under the design loads.

The design characteristic strength (f_{cd}) is calculated as:

$$f_{cd} = f_{ck} / \gamma$$

The value of γ depends on the specific limit states and the level of reliability required. In Norway, the material factor γ is typically taken as 1.5 for the ultimate limit state design (ULS) and 1.0 for the serviceability limit state design (SLS). These values ensure an appropriate level of safety for the intended design life of the structure.

It's important to note that these values are general guidelines, and the specific material factors for concrete design in Norway may vary based on the applicable design standards, regulations, and specific project requirements. Consulting the Norwegian design standards, such as NS-EN 1992-1-1 series for concrete, will provide the accurate values and recommendations for material factors in concrete design.

In concrete design engineers would want to assure that the stresses in an element is less than f_{cd}

Timber

In timber design, material factors are used to account for the variability in timber properties and load effects. It is applied to the characteristic strength of timber (f_{mk}) to determine the design strength (f_d) of timber.

The design strength (f_d) is calculated as:

$$f_d = f_{mk} / \gamma$$

The value of γ depends on the timber species, grade, and specific application. In Norway, different values of γ are provided based on the reliability level and intended service class of the structure. For example, γ values of 1.2 or 1.3 are commonly used for normal reliability levels and service classes.

It's important to note that these values are general guidelines, and the specific material factors for timber design in Norway may vary based on the applicable design standards, regulations, and specific project requirements. Consulting the Norwegian design standards, such as NS-EN 1995 series for timber, will provide the accurate values and recommendations for material factors in timber design.

In timber design engineers would want to assure that the stresses in an element is less than f_d