Dimensional Stability

- Review
- Causes of non-linearity (in a short and long time) in the s-s relation of concrete are discussed.
- The stress effect resulting from drying shrinkage and visco-elastic strains in concrete are not the same; however, with both phenomena, the underlying causes and the controlling factors have much in common
- Such as aggregate content, aggregate stiffness, water content, cement content, time of exposure, relative humidity, size and shape of concrete members
- Thermal shrinkage is of great importance in large concrete elements.

Types of deformation and their significance

- Elastic behavior
- *Non-linearity of the s-s relationship*
- *The causes of non-lineality has been explained from the studies on the process of progressive micro cracking in concrete under load* .

- 4 stages

4 stages

- Stage1: below about 30% of the ultimate load, the ITZ cracks remain stable .

- Stage2: above 30% of the ultimate load, the ITZ micro cracks begin to increase in length, a stable system of micro cracks in ITZ .

- Stage3: 50-60% of the ultimate load, cracks begin to form in the matrix.
- With further increase in stress up to 75%
- Crack system in ITZ unstable .

- Stage4: above 75%, the crack system is becoming continuous due to the rapid propagation of cracks in both the matrix and ITZ .

Types of elastic module 12･18

- 1.tangent modulus
- 2.secant modulus
- 3.chord modulus
- 4.dynamic modulus (initial tangent modulus)
- The dynamic modulus of elasticity, corresponding to a very small instantaneous strain, is approximately given by the initial tangent modulus, which is the tangent modulus for a line drawn at the origin .

- Poisson's ratio
- The ratio of the lateral strain to axial strain within the elastic range is called Poisson's ratio. Vary between 0.15 and 0.20 .

Drying shrinkage and creep

- It is desirable to discuss both the drying shrinkage and creep together.
- 1.originate the same source: the hcp
- 2.the strain-time curve are very similar
- 3.the factors are very similar
- 4.400-1000x10exp(-6)
- 5.both are partially reversible .

Causes

- Drying shrinkage
- Under dry or sustained stress,
- Lose a large amount of the physically absorbed water
- Assumed to be very related mainly to the removal of absorbed water .
- Hydrostatic tension in small capillaries <50nm

Creep

- In creep: addition to this, lose water by stress and,
- At stress levels greater than 30to40% of the ultimate load, clearly shows the contribution of the ITZ micro cracks, it means irreversible.

- **Effect of loading and humidity conditions on drying shrinkage and visco elastic behavior Table 4-3 important**
- Application of a constant stress on a concrete specimen under condition of 100%RH, leads to an increase of strain over time, which is called basic creep .

- Creep is simply considered as the deformation under load in excess of the sum of the elastic strain and free drying shrinkage strain
- Note that presentation of creep data can be done in different ways, which have given rise to special terminology. For instance, specific creep is the creep strain per unit of applied stress and creep coefficient is the ratio of creep strain to elastic strain .
- Strictly, basic creep is defined in 100% R.H.

Reversibility

- Drying SH and creep exhibit a degree of irreversibility
- The instantaneous recovery is followed by a gradual decrease in strain called creep recovery.

Factors affecting drying shrinkage and creep

- The interaction among these factors are quite complex and not easily understood
- Materials and mix-proportion
- The main source of moisture related deformation is the hydrated cement paste
- Most theoretical expression for predicting the drying shrinkage and creep assume that the elastic modulus of concrete can provide an adequate measure of the degree of restraint against deformation .

図5.3.5 クリープ—時間曲線

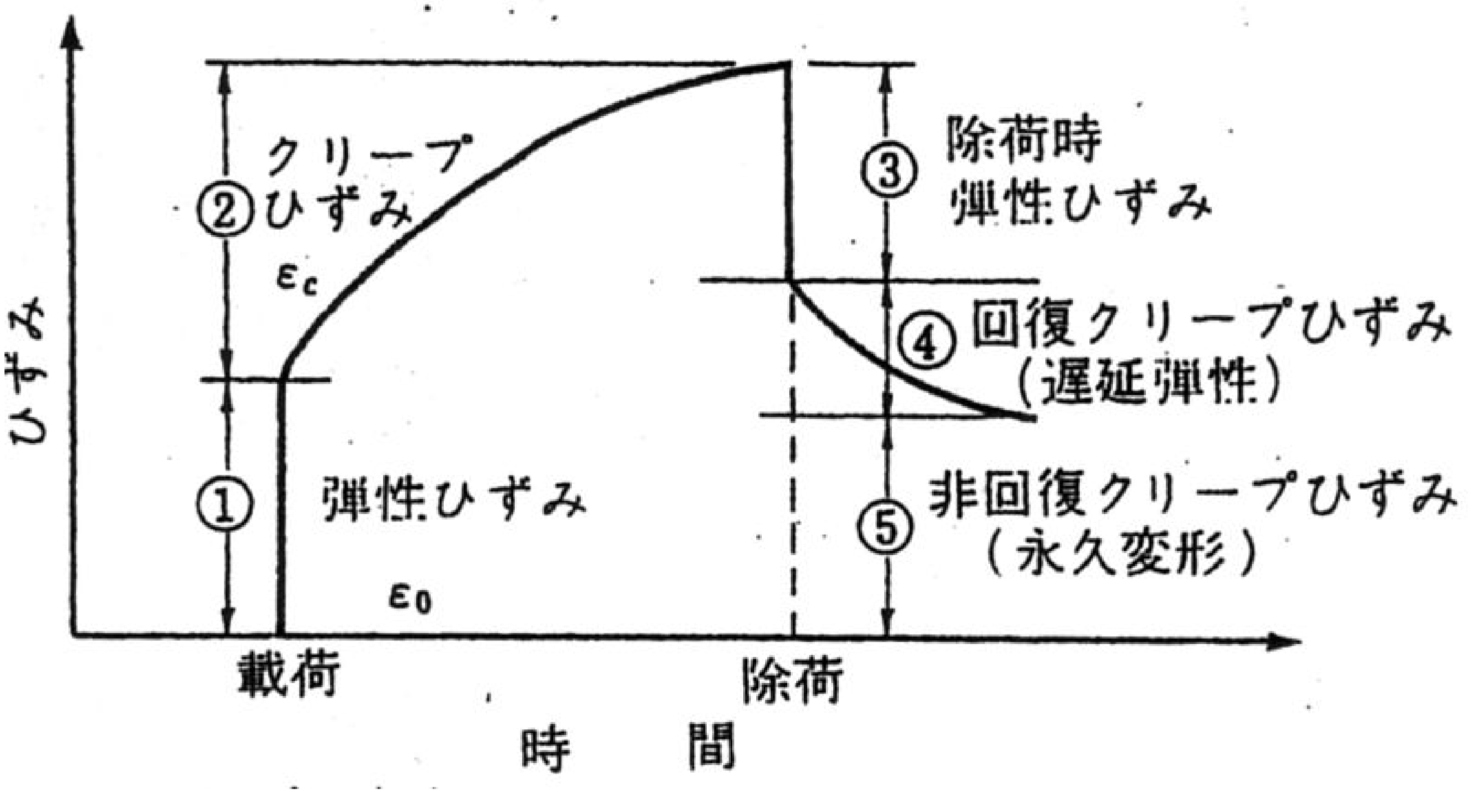
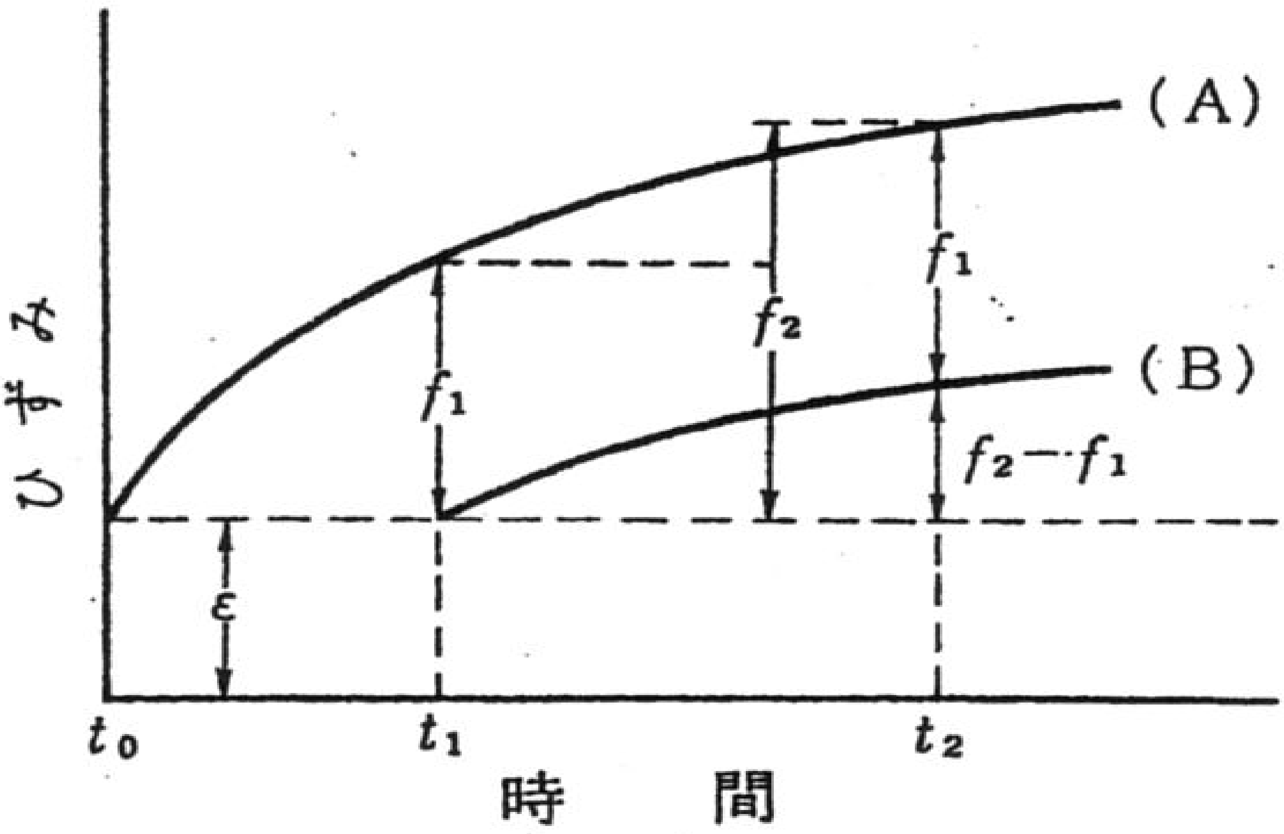


図5.3.6 Whitneyの法則



Powers Sc/Sp=(1-g)exp(n)for drying shrinkage

- g:the volume fraction of the aggregate,
- So, 1-g is related to the amount of paste.
- n:1.2-1.7
- Cc/Cp=(1-g)exp(m)
- The expression for creep and drying shrinkage are similar .

$$(1-g)^{n}$$

$$(1-g)^{m}$$

- Also the modulus of elasticity of the aggregate is important
- Obviously, with a given aggregate and mix proportion, if the type of cement influences the strength of concrete at the time of application of load, the creep of concrete will be affected.
- Concrete containing capable of pore refinement usually show higher drying shrinkage and creep 3 to 20nm <50nm .
- So, sometimes, stronger means higher shrinkage and creep.

Time and humidity

- Diffusion of the absorbed water and the water held by capillary tension in small pores (<50nm) of hydrated cement paste to large capillary pores takes place over long periods. SH
- 20-25% of the 20 years: in 2weeks
- 50-60% 3months
- 75-80% 1year
- Similar results were found for the creep strains.
- (depend on the size.)

Geometry of the concrete element

- The rate of water loss would obviously be controlled by the length of the path traveled by the water.
- Effective or theoretical thickness, which is equal to the area of the section divided by the perimeter in contact with the atmosphere . A/S

Additional factors affecting creep

- curing history
- temperature
- intensity of the applied stress: the proportionality is valid as long as the applied load is in the linear domain of s-s relationship.   Up to —30%
- why 30%?

Thermal shrinkage 1･8

- With low tensile strength material, such as concrete, it is the shrinkage strain from cooling that is more important than the expansion from heat generated by cement hydration 10x10-6/degree
- However, there is some relaxation of stress due to creep,
- The resulting tensile stress:
  σ =KrxE/(1+ ϕ)x α Δ T
- Kr: degree of restraint

- Factors affecting thermal stresses
- Degree of restraint
- Assuming a rigid foundation, there will be a full restraint at the concrete-rock interface (K_r=1.0)

ACI recommends the following multiplier

- $K=1/(1+AgE/AfEf)$
- Af:area of foundation
- temperature change (ΔT)
- We can controll ΔT.
- ΔT=(PLACEMENT TEMP OF FRESH CONCRETE)+(ADIABATIC TEMP RISE)-(ambient or service temp) – (temp drop due to heat losses)

ΔT

- Placement temp: pre-cooling of fresh concrete, chilled aggregate
- and/or ice shavings
- The rate and magnitude of the adiabatic temperature rise is a function of the amount, composition and fineness of cement, and its temperature during hydration
- The composition of cement and the placement temp appear to affect mainly ***the rate of heat generation*** rather than the total heat produced .

ΔT

- The inclusion of a pozzolan as a partial replacement for cement
- Heat losses depend on the thermal properties of concrete ,and the construction technology adopted. a concrete structure can lose heat through its surface
- Surface transmission coefficient for different isolation environment .

Thermal properties of concrete

- coefficient of thermal expansion
- specific heat,
- thermal conductivity,
- thermal diffusivity
- (thermal diffusivity=thermal conductivity/(density x specific heat)

Extensibility and cracking

- The primary significance of deformation is whether or not their interaction would lead to cracking
- the magnitude of the shrinkage is one of the factor governing the cracking of the concrete
- modulus of elasticity::
- creep
- tensile strength:

- obviously, for a minimum risk of cracking, the concrete should undergo not only less shrinkage but also should have a high degree of extensibility
- (i.e., low elastic modulus, high creep, and high tensile strength)
- in general, high strength concrete is more prone to cracking because of greater thermal shrinkage and lower stress relaxation
- With thin sections, the effect of drying shrinkage strain is more important.
- The cracking behavior of concrete in the field can be more complex .