CONCRETE TECHNOLOGY MODULE SEMESTER 1 – LECTURE 7

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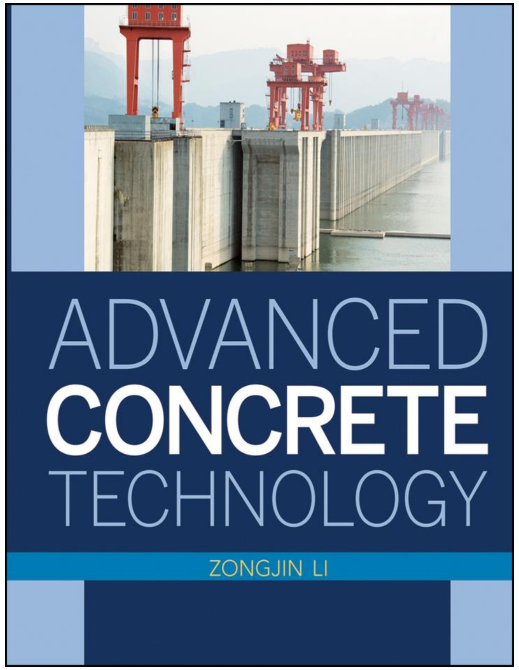
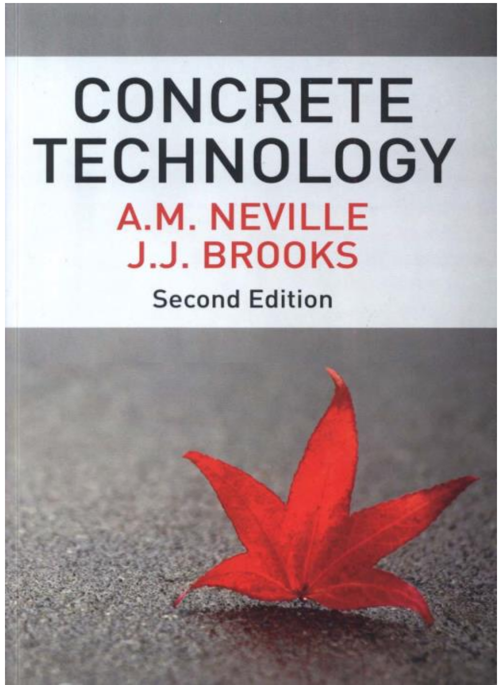
SEMESTER 1 OUTLINE

Item	Subject	Item	
1	**Introduction: Cement and Aggregate**		
2	**Manufacturing of concrete** - Mixing - Transportation - Placing and compaction - Curing - Finishing	4	**Strength of Concrete** - Compressive strength - Tensile strength - Modulus of rupture - Bond strength with steel reinforcement - Factors affecting concrete strength - Factor affecting concrete test
3	**Properties of Fresh Concrete** - Workability and Consistency - Segregation and Bleeding - Pressure on form work - Stripping of form	5	**Deformation of Concrete** - Creep - Shrinkage - Modulus of elasticity and Poisson's ratio

REFERENCES

- Concrete technology by Dr. Moaid Nory
- Advanced concrete technology by Zongjin Li
- Concrete Technology -2dn Ed by A.M. NEVILLE





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2.1.1 Effects of aggregates

(a) *Aggregate in fresh and plastic concrete*:

When concrete is freshly mixed, the aggregates are suspended in the cement–water–air bubble paste. The behaviour of fresh concrete, such as fluidity, cohesiveness, and rheological behaviour, is largely influenced by the amount, type, surface texture, and size gradation of the aggregate. The selection of aggregate has to meet the requirement of the end use, i.e., what type of structure to be built.

(b) *Aggregate in hardened concrete*:

Although there is little chemical reaction between the aggregate and cement paste, the aggregate contributes many qualities to the hardened concrete. In addition to reducing the cost, aggregate in concrete can reduce the shrinkage and creep of cement paste. Moreover, aggregates have a big influence on stiffness, unit weight, strength, thermal properties, bond, and wear resistance of concrete.

2.1.2 Classification of aggregates

Aggregates can be divided into several categories according to different criteria, such as size, source, and unit weight.

(a) In accordance with size

1. Coarse aggregate: Aggregates predominately retained on a No. 4 (4.75-mm) sieve are classified as coarse aggregate. Generally, the size of coarse aggregate ranges from 5 to150 mm. **For normal concrete used for structural members such as beams and columns, the maximum size of coarse aggregate is about 25 mm**. For mass concrete used for dams or deep foundations, the maximum size **can be as large as 150 mm**. Figure 2-1 shows some examples of coarse aggregates.

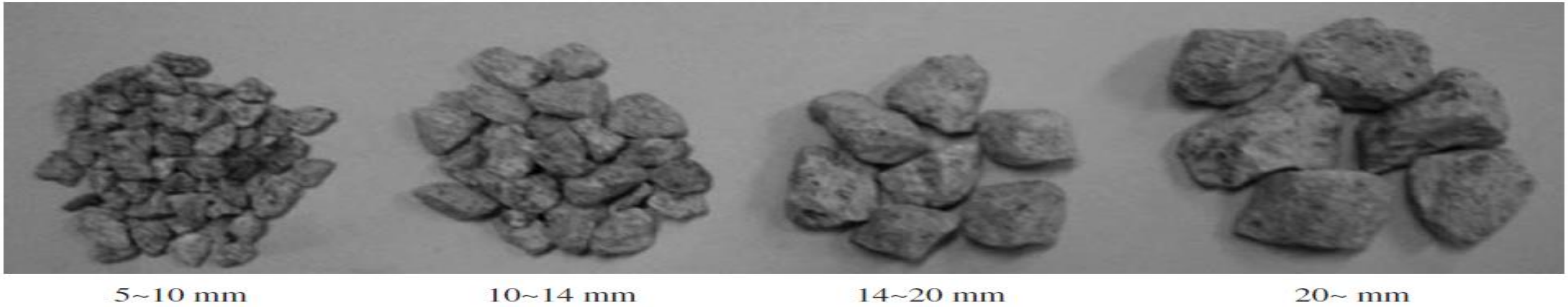

Figure 2-1 Different sizes of coarse aggregates

***2. Fine aggregate (sand)*:** Aggregates passing through a No. 4 (4.75 mm) sieve and predominately retained on a No. 200 (75 μm) sieve are classified as fine aggregate. River sand is the most commonly used fine aggregate. In addition, crushed rock fines can be used as fine aggregate. **However, the finish of concrete with crushed rock fines is not as good as that with river sand.** Figure 2-2 shows the profile of sand.

(b) In accordance with source

***1. Natural aggregates*:** This kind of aggregate such as **sand and gravel** is taken from natural deposits without changing the nature during production.

2. Manufactured (synthetic) aggregates *(see Figure* 2-3): These kinds of aggregate are manmade materials, resulting from products or by-products of industry. Some examples are blast furnace slag and lightweight aggregate.

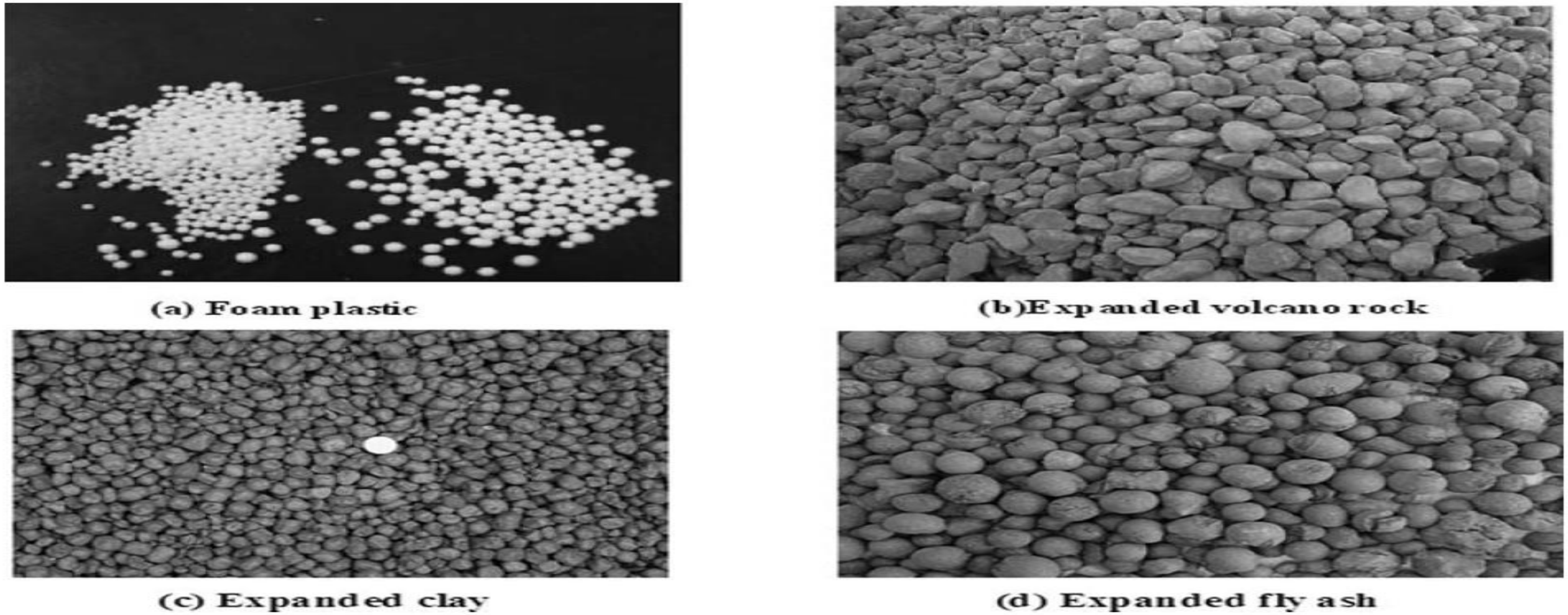

Figure 2-3 Synthetic aggregates

(c) In accordance with unit weight

1. Ultra-lightweight aggregate: The unit weight of such aggregates is less than 500 kg/m3, including **expanded perlite** and foam plastic. The concrete made of ultra-lightweight aggregates has a bulk density from 800 to 1100 kg/m3, depending on the volume fraction of aggregate. **Such a concrete can be used only as non-structural members, like partition walls.**

2. Lightweight aggregate: The unit weight of such aggregates is between 500 and 1120 kg/m3. Examples of lightweight aggregates include cinder, blast-furnace slag, volcanic pumice, and expanded clay. The concrete made of lightweight aggregate has a bulk density between 1200 and 1800 kg/m3. **Such concrete can be either a structural member or non-structural member, depending what type of aggregate is used.**

***3. Normal-weight aggregate*: An aggregate with a unit weight of 1520–1680 kg/m3 is classified as normal-weight aggregate. Sand, gravel, and crushed rock belong to this category and are most widely used. Concrete made with this type of aggregate has a bulk density of 2300–2400 kg/m3. **It is the main concrete used to produce important structural members.**

4. Heavy-weight aggregate: If the unit weight of aggregate is greater than 2100 kg/m3, it is classified as heavy-weight aggregate. Materials used as heavy-weight aggregate are iron ore, crashed steel pieces, and magnesite limonite. The bulk density of the corresponding concrete is greater than 3200 kg/m3 and can reach 4000 kg/m3. **This kind of concrete has special usage, like radiation shields in nuclear power plants, hospitals, and laboratories. It can also be used as sound-shielding material.**

2.1.3 Properties of aggregates

2.1.3.1 Moisture conditions

The moisture condition defines the presence and amount of water in the pores and on the surface of the aggregate. There are four moisture conditions, as demonstrated in Figure 2-4.

(a) ***Oven dry (OD)***: This condition is obtained by keeping the aggregate in an oven at a temperature of 110◦C long enough to drive all water out from internal pores and hence reach a constant weight.

(b) ***Air dry (AD)***: This condition is obtained by keeping the aggregate at ambient temperature and ambient humidity. Under such condition, pores inside of aggregate are partly filled with water. When aggregate is under either the OD or AD condition, it will absorb water during the concrete mixing process until the internal pores are fully filled with water.

(c) ***Saturated surface dry (SSD)***: In this situation, the pores of the aggregate are fully filled with water and the surface is dry. This condition can be obtained by immersing coarse aggregate in water for 24 h followed by drying of the surface with a wet cloth. When the aggregate is under the SSD condition, it will neither absorb water nor give out water during the mixing process. Hence, it is a balanced condition and is used as the standard index for concrete mix design.

(d) ***Wet (W)***: The pores of the aggregate are fully filled with water and the surface of the aggregate has a film of water. When aggregate is in a wet condition, it will give out water to the concrete mix during the mixing process. Since sand is usually obtained from a river, it is usually in a wet condition.

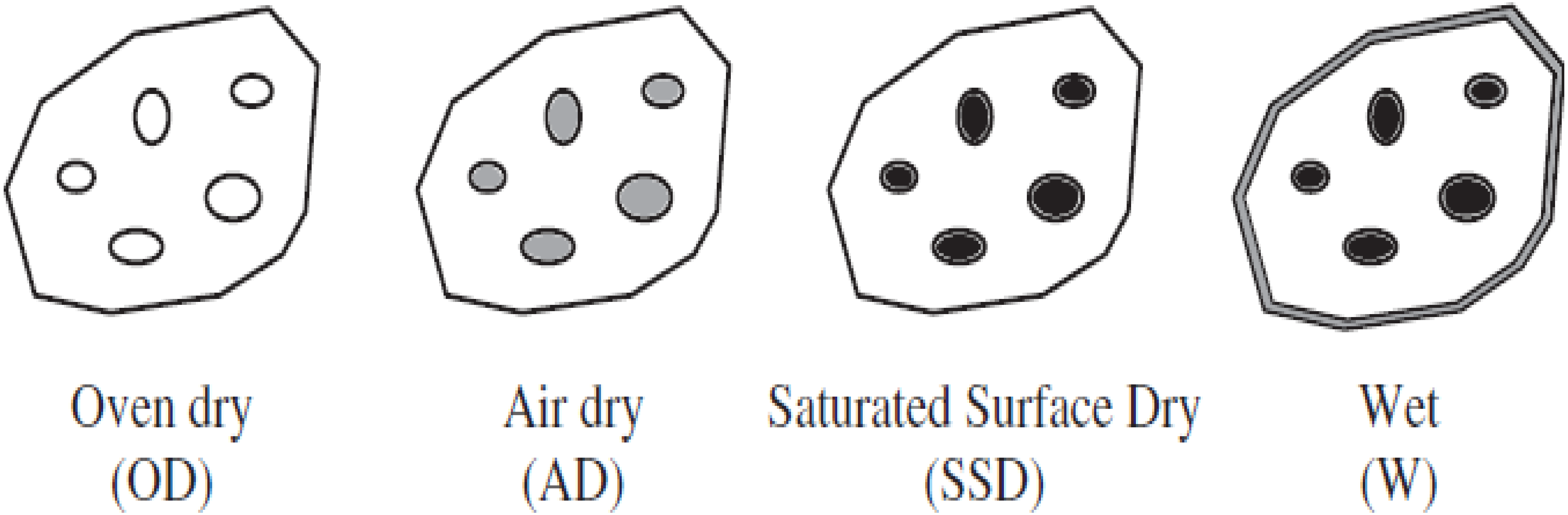

Figure 2-4 Moisture conditions of aggregates

2.1.3.2 Moisture content (MC) calculations

The moisture content of aggregates can be calculated with respect either the OD or SSD condition.

(a) For the oven dry condition

$$MC\,(OD) = \frac{W_{stock} - W_{OD}}{W_{OD}} \times 100\% \tag{2-1}$$

where W_{stock} is the weight of aggregate in the stock condition, and W_{OD} the weight of oven-dried aggregates. It can be seen that MC_{OD} is a nonnegative value.

(b) For the saturated surface dry condition

$$MC\,(SSD) = \frac{W_{stock} - W_{SSD}}{W_{SSD}} \times 100\% \tag{2-2}$$

where W_{SSD} is the weight of aggregate in the SSD condition. As W_{stock} can be greater than, equal to, or less than W_{SSD}; MC_{SSD} can be greater than, equal to, or less than zero.

(c) Absorption capacity

$$AC = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% \tag{2-3}$$

Absorption capability of an aggregate is defined as the total amount of water that can be taken by an aggregate from the OD to the SSD condition.

It should be noted that in designing a concrete mix, the moisture content usually uses the SSD condition as a reference, because it is an equilibrium condition at which the aggregate will neither absorb water nor give up water to the paste.

- Thus, if the MC_{SSD} value is positive, it means that the aggregate is under a surface moisture condition.
- If it is negative, it means that the pores in the aggregate are only partly filled with water.
- The amount of water used for mixing concrete has to be adjusted according to the MC_{SSD} value in order to keep a correct *w*/c ratio,
- especially for a high-strength concrete in which a small *w*/c ratio is used, and the amount of adjusted water involved in MC can easily be a large portion of the total amount of water in the mixture.

2.1.3.3 Density and specific gravity

Since aggregates are porous materials, even a single piece of aggregate contains both solid material volume and pores volume. Hence, two types of aggregate density are defined.

Density (*D*) is defined as the weight per unit volume of solid material only, excluding the pores volume inside a single aggregate:

$$D = \frac{\text{weight}}{V_{\text{solid}}}$$

Bulk density (BD) is defined as the weight per unit volume of both solid material and the pores volume inside a single aggregate:

$$\text{BD} = \frac{\text{weight}}{V_{\text{solid}} + V_{\text{pores}}}$$

where BD can be either **BD_{SSD} or BD_{AD}** according to the moisture condition of the aggregate when it is weighed.

Specific gravity (SG) is a ratio of density or bulk density of aggregate to density of water. Or SG is the mass of a given substance per unit mass of an equal volume of water. Depending on the definition of volume, the specific gravity can be divided into **absolute specific gravity (ASG) and bulk specific gravity (BSG).**

$$\text{ASG} = \frac{\dfrac{\text{weight of aggregate}}{V_{\text{solid}}}}{\text{density of water}} = \frac{D}{\rho_{\text{w}}}$$

$$\text{and} \quad \text{BSG} = \frac{\dfrac{\text{weight of aggregate}}{V_{\text{solid}} + V_{\text{pores}}}}{\text{density of water}} = \frac{\text{BD}}{\rho_{\text{w}}}$$

In practice, the BSG value is the realistic one to use since the effective volume that an aggregate occupies in concrete includes its internal pores. The BSG of most rocks is in the range of 2.5 to 2.8. Similar to BD, BSG can be either BSG_{SSD} or BSG_{AD} according to the moisture condition of the aggregate. The BSG can be determined using the so-called displacement method.

In this method, Archimedes' principle is utilized. The weight of aggregate is first measured in air, e.g., under the SSD condition, and is denoted as W_{SSD} in air. Then, the weight of the sample is measured in water, denoted as WSSD in water. Thus, we have

$$BSG_{SSD} = \frac{W_{SSD\ in\ air}}{W_{displacement}} = \frac{W_{SSD\ in\ air}}{W_{SSD\ in\ air} - W_{SSD\ in\ water}}$$

where $W_{displacement}$ is the weight of water displaced by the aggregates.


Thank you for
your
attention!