Standardization of concrete for radiation shielding
- Discussion on possible collaboration works-

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Background

Concrete is very useful and inexpensive material for radiation shielding

- density for photon shielding, hydrogen for neutron
- easy to apply various structure and fitting the given shape
- contain certain physical properties
- very inexpensive and long life
- reliable for durability

HOWEVER

- variety of material depending on each region
- Quite few uncertain exist for use

Motivation

- Very old and uncertain concrete data is used by the calculation for radiation shield

  ANL-5800 (1963), ANL-6443 (1961),JAERI-M-6928 (February 1977)

  None or few description which is common as building material

- Concrete composite data is needed to describe and establishment of concept of concrete for radiation is required. ⇒ “standard concrete for shield”
- While there is no “standard concrete” at construction point view.

Organization

Working Group under Standardization Committee of Atomic Energy Society of Japan
Member : 25 experts form academia, supplier of NPP, construction, simulation …

When and how use “Standard” ?

- Design phase for plan of facility and/or building

  no fixed data, no material exits for construction
- With reasonable assumption
- Not for benchmark, not for exiting facilities which had already the reliable data
- Applicable for the regional regulation with certain likelihood at time for plan of the facility

Description of concrete

- Mixture table ------ design of concrete

  ⇔ contents of oxides ⇔ contents of elements

- Consistence materials of concrete

Aggregate	course	sandstone, Andesite
	fine	sand,
Cement		Portland cement
additives		fly ash, silica fume
water		

Consistence of concrete

Element	Oxygen(Molecule)	Material
Silicon: Si	SiO2, 3CaO･Si2, 2CaO･SiO2	Aggregate, Cement
Calcium: Ca	3CaO･Si2, 2CaO･SiO2, CaCO3	Cement, Aggregate
Aluminum: Al	3CaO･Al2O3, Al2O3	Cement, Aggregate
Oxygen: O	SiO2, 3CaO･Si2, 2CaO･SiO2	Aggregate, Cement, water
Hydrogen: H	H2O	Water, cement
Carbon: C	CaCO3	aggregate
Iron: Fe	3CaO･Al2O3･Fe2O3, Fe2O3	Aggregate, cement

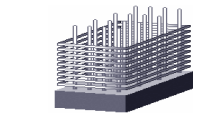
Atomic density
(atom/cm^3)

Unite volume mass
(kg/m^3)

Why and how possible “Standard” ?

- As shielding point view which is focusing elements, concrete should not be divertible, while it is divertible and has regional dependence as building and/or civil aspect which is focusing materials.
- Rough sensitivity analyses for various type of concrete based on variety of law material stock library
- It should be concrete from material point of view as well as shielding aspect

Material stock library (3000～)



reinforced concrete

steel bar

concrete

iron ore

coke

cement

aggregate

iron ore

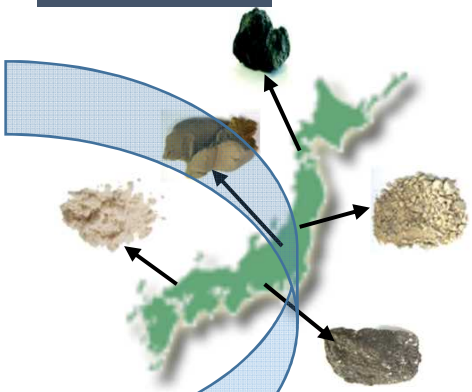
clay

limestone

gypsum

quartzite

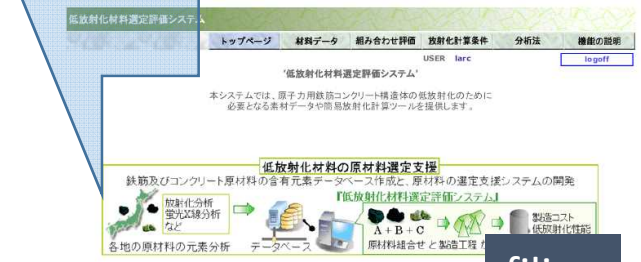
Gathering



Sampling

Material stock library

analyzing



filing

Road to Standard

- Standard concrete for shielding
- Represent of shielding concrete

  represent of

  mixture table, aggregates, cements, additives

- Averaged data from supplement of the above

Standard concrete

representative concrete

averaged concrete

Mixture table - Oxide - Element composition for AV03

Mixture Table (kg/m^3)				
Water	Aggregate		cement	Additive
	Fine	Cource		
162	773	1093	300	0

Oxiside: g/cm^3												
H_2O	CO_2	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	K_2O	CaO	TiO_2	MnO	Fe_2O_3
0.120	0.051	0.053	0.048	0.244	1.264	0.002	0.005	0.051	0.316	0.012	0.001	0.097

Element: atom/cm^3													×E-24
H	C	O	Na	Mg	Al	Si	P	S	K	Ca	Ti	Mn	Fe
8.02E-03	7.02E-04	4.13E-02	1.02E-03	7.18E-04	2.88E-03	1.27E-02	1.94E-05	3.76E-05	6.47E-04	3.40E-03	8.81E-05	1.10E-05	7.33E-04

Trail introduction of averaged concrete

Material	
Cement	300
Aggregate fine	773
course	1093
water	162

Element	Atomic weight	Averaged 2003	Free water 0.04g/cm^3	Free water 0.10g/cm^3	Free water 0.18g/cm^3
H	1.008	8.02E-03	6.69E-03	1.07E-02	1.60E-02
C	12.01	7.02E-04	7.02E-04	7.02E-04	7.02E-04
O	16.00	4.13E-02	4.06E-02	4.26E-02	4.53E-02
Na	22.99	1.02E-03	1.02E-03	1.02E-03	1.02E-03
Mg	24.31	7.18E-04	7.18E-04	7.18E-04	7.18E-04
Al	26.98	2.88E-03	2.88E-03	2.88E-03	2.88E-03
Si	28.09	1.27E-02	1.27E-02	1.27E-02	1.27E-02
P	30.97	1.94E-05	1.94E-05	1.94E-05	1.94E-05
S	32.07	3.76E-05	3.76E-05	3.76E-05	3.76E-05
K	39.10	6.47E-04	6.47E-04	6.47E-04	6.47E-04
Ca	40.08	3.40E-03	3.40E-03	3.40E-03	3.40E-03
Ti	47.87	8.81E-05	8.81E-05	8.81E-05	8.81E-05
Mn	54.94	1.10E-05	1.10E-05	1.10E-05	1.10E-05
Fe	55.85	7.33E-04	7.33E-04	7.33E-04	7.33E-04
density g/cm^3		2.26	2.24	2.3	2.38

Aggregate（1996）
  supplement：production in Japan
  element ratio：domestic report
Cement（2000）
  cement association report
Mixture table：
  「handbook for civil engineer 1985」

Likelihood - width of deviation

- Regional deviation

  Variety of aggregates regionally and additives for use

- Deviation during construction on the facility site

  Dependence on workability, supplement companies, ……

- Water contents in the concrete - three states of the water

  Free water (below 105 ℃)

  Chemical bonding water from cement hydrogen reaction

  Crystalized water in aggregate

- Density

Possible collaboration works

FUJITA
Daiwa House Group

Step one:

comparison of concrete composite data in codes

- Does your code include the ordinary concrete composite data ?
- if yes, please send data
- if no, how do you answer the person who wants to use ?
- Make table focusing density and water contents

Step two:

Another comparison in case of actual shielding design for accelerator facilities related regulation

Step three:

Discussion on the standard concrete for shielding and road toward

Comparison of sensitivity analyses between codes and/or data

Example for data in codes

Geant4 from Dr.Koi

Composition of CONCRETE, PORTLAND:

Density (g/cm^3) = 2.30000E+00

Mean Excitation Energy (eV) = 135.200000

COMPOSITION:	
Atomic number	**Fraction by weight**
1	0.010000
6	0.001000
8	0.529107
11	0.016000
12	0.002000
13	0.033872
14	0.337021
19	0.013000
20	0.044000
26	0.014000

http://physics.nist.gov/cgi-bin/Star/compos.pl?matno=144

Phits 2.87

```
[ Material ]
$[m30 Fe shield D=-7.2]
m30       Fe  8.4760E-02

$[m40 Concrete D=-2.2]
m40        H  1.3407e-2
           C  1.1030e-3
           O  4.3887e-2
          Al  1.7971e-3
          Si  1.6123e-2
          Ca  1.8940e-3
          Fe  3.3448e-4
```

Lecture input file
Recommendation > shielding

Example for data in actual facilities

Concrete data in construction site

Composition of major elements by analyses

Mixture table design report (inspection report for concrete) including information of aggregate and cement

Sampling of constructed concrete

Test samples for physical properties

We might be able to analyze

使 用 材 料

セメント	生産者名	太平洋セメント株式会社			密度 g/cm	3.16	Na_2Oeq % 0.69
混和材①	製品名	-	種類	-	密度 g/cm	-	Na_2Oeq % -
混和材②	製品名	-	種類	-	密度 g/cm	-	Na_2Oeq % -

骨材	No.	種類	産地又は品名	アルカリシリカ反応性による区分		粒の大きさの範囲	粗粒率又は実積率	密度 g/cm		微粒分量の範囲 %
				区分	試験方法			絶乾	表乾	
細骨材	①	砕砂	青梅産	A	化学法	5以下	3.10	2.58	2.62	0.5～4.5
	②	砕砂	仙波産	A	モルタルバー法	5以下	2.84	2.64	2.68	0.5～4.5
	③	砂	成田産	A	化学法	2.5以下	1.75	2.54	2.60	-
粗骨材	①	砕石	青梅産	A	化学法	20～ 5	59.0	2.65	2.67	0～1.0
	②	-	-	-	-	-	-	-	-	-
	③	-	-	-	-	-	-	-	-	-

混和剤①	製品名	フローリックSP500S	種類	高性能AE減水剤標準形Ⅰ種
混和剤②		-		-
混和剤③		-		-

細骨材の塩化物量	0.001 %	水の区分	上水道水	目標スランプ	- cm
				固形分率	- %

配 合 表 (kg/m³)

セメント	混和材①	混和材②	水	細骨材①	細骨材②	細骨材③	粗骨材①	粗骨材②	粗骨材③	混和剤①	混和剤②	混和剤③
328	-	-	175	445	273	177	897	-	-	3.12	-	-

水セメント比	53.4 %	水結合材比	- %	細骨材率	50.3 %

細骨材混合比(容積) 砕砂:石灰砕砂:山砂=50:30:20

Typical example for mixture table design report in Japanese

Thank you for your attention !
And welcome for any information related shielding concrete

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