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Elastomeric seismic-protection isolators —

Part 7: Relationship of the ISO 22762 series to the design and testing of seismic isolation systems

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Foreword

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This document was prepared by Technical Committee ISO/TC 45, *Rubber and rubber products*, Subcommittee SC 4, *Products (other than hoses)*.

A list of all parts in the ISO 22762 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Elastomeric isolators are one of the most popular types of seismic isolation systems for buildings worldwide. Structural engineers must comply with national building code requirements, or guidelines if detailed code provisions for isolation do not exist, and generally that means designing in accordance with a standard, such as ASCE/SEI 7-22. In these codes and guidelines, the requirements for isolators must satisfy design demands determined by structural seismic response analysis. The ISO 22762 series provides detailed requirements for testing and design of elastomeric isolators and gives different requirements (grades) according to the target performance level for the isolation system. This new document is intended to explain the relationship between the requirements in national seismic codes with ASCE/SEI 7-22 used by way of example throughout, and ISO 22762 series, with the goal of allowing structural engineers to more effectively, and more widely, make use of ISO 22762 series when designing seismically-isolated buildings. ASCE/SEI 7-22 is used throughout this document as an example building code for seismically-isolated buildings, and any reference to "seismic code" may be understood to refer to that document. The concept of this document is given in Figure 1.

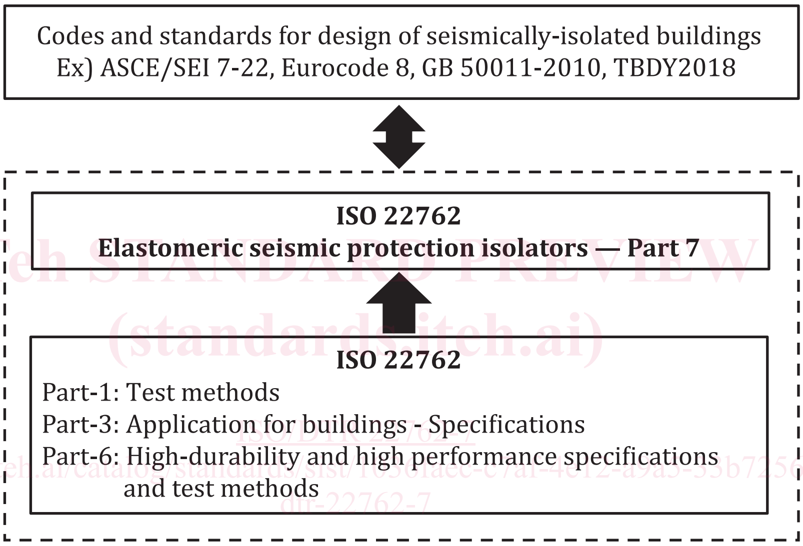

Figure 1 — Conceptual diagram showing the role of ISO/TR 22762-7

Elastomeric seismic-protection isolators —

Part 7: Relationship of the ISO 22762 series to the design and testing of seismic isolation systems

1 Scope

This document explains the relationship of the ISO 22762 series to the design and testing of seismic isolation systems, including the relationship to national seismic codes.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp/

— IEC Electropedia: available at http://www.electropedia.org/

3.1
breaking
rupture of *elastomeric isolator* (3.6) due to compression- (or tension-) shear loading

3.2
buckling
state when *elastomeric isolators* (3.6) lose their stability under compression-shear loading

3.3
compressive properties of elastomeric isolator
K_v
compressive stiffness for all types of rubber bearings

3.4
design compressive stress
long-term compressive force on the *elastomeric isolator* (3.6) imposed by the structure

3.5
design shear strain
shear strain of elastomeric isolator at design shear displacement

3.6
elastomeric isolator
rubber bearing, for seismic isolation of buildings, bridges and other structures, which consists of multi-layered vulcanized rubber sheets and reinforcing steel plates

EXAMPLE High-damping rubber bearings, linear natural rubber bearings and lead rubber bearings.

3.7
first shape factor
ratio of effectively loaded area to free deformation area of one inner rubber layer between steel plates

3.8
high-damping rubber bearing
HDR
elastomeric isolator with relatively high damping properties obtained by special compounding of the rubber and the use of additives

3.9
inner rubber
rubber between multi-layered steel plates inside an *elastomeric isolator* (3.6)

3.10
lead rubber bearing
LRB
elastomeric isolator (3.6) whose *inner rubber* (3.8) with a lead plug or lead plugs press fitted into a hole or holes of the isolator body to achieve damping properties

3.11
linear natural rubber bearing
LNR
elastomeric isolator (3.6) with linear shear force-deflection characteristics and relatively low damping properties, fabricated using natural rubber

Note 1 to entry: Any bearing with relatively low damping can be treated as an LNR bearing for the purposes of isolator testing.

3.12
maximum compressive stress
peak stress acting briefly on *elastomeric isolators* (3.6) in compressive direction during an earthquake

3.13
maximum shear strain
shear strain of elastomeric isolator at maximum shear displacement

3.14
property modification factor
factor to account for a variation in physical property from a standard value, due to effects such as temperature, rate of loading, manufacturing variations, ageing and environmental exposure

3.15
compressive stress
nominal compressive stress
long-term stress acting on *elastomeric isolators* (3.6) in compressive direction as recommended by the manufacturer for the isolator, including the safety margin

3.16
production test
project specific test to verify that the isolator manufactured has the required performance prior to shipping

3.17
prototype test
project specific test to verify that the designed isolator has the required performance

3.18
qualification test
test to demonstrate the isolator performance in various test items, which is conducted by manufacturer and whose data is submitted for approval of structural engineer as one of bidding documents

 PROOF/ÉPREUVE

3.19
routine test
test for quality control of the production isolators during and after manufacturing

3.20
second shape factor
<circular elastomeric isolator> ratio of the diameter of the *inner rubber* (3.8) to the total thickness of the inner rubber <rectangular or square elastomeric isolator> ratio of the effective width of the *inner rubber* (3.8) to the total thickness of the inner rubber

3.21
seismic code
building code that defines regulatory requirements for the earthquake design of buildings, and which may include provisions for seismic isolation

3.22
shear properties
shear properties of elastomeric isolators
comprehensive term that covers characteristics determined from isolator tests:

— shear stiffness, K_h, for LNR

— shear stiffness, K_h, and equivalent damping ratio, h_{eq}, for HDR and LRB

— post-yield stiffness, K_d, and characteristic strength, Q_d, for LRB

3.23
standard value
value of isolator property defined by manufacturer based on the results of type test

3.24
structural engineer
engineer responsible for the design of the seismically-isolated building and for specifying the requirements for *elastomeric isolators* (3.6)

3.25
type test
test for verification of either material properties and isolator performances during development of the product or that project design parameters are achieved

3.26
ultimate property
property at either buckling, breaking, or roll-out of an isolator under compression-shear loading

4 Symbols

For the purposes of this document, the symbols given in Table 1 apply.

Table 1 — Symbols and descriptions

Symbol	Description
D_L	dead load of building-superstructure
D_D	displacement at the centre of stiffness of the isolation system under the Design Earthquake[a] (from seismic code)

[a] The terms “Design Earthquake” and “Maximum Earthquake” are used for simplicity herein to facilitate explanation of concepts and relationships for two earthquake hazard levels. It is recognized that these terms are not directly used by ASCE 7-22 or other building codes. The test parameters presented in subsequent tables (give table numbers) assume that the Design Earthquake demand is 2/3 of the Maximum Earthquake Demand.

Table 1 *(continued)*

Symbol	Description
D_M	maximum displacement at the center of stiffness of the isolation system under the Maximum Earthquake[a] (from seismic code)
D_{TM}	maximum displacement of an element of the isolation system under the Maximum Earthquake[a], including torsional effects (from seismic code)
E_L	load of building-superstructure in vertical direction generated during earthquake
h_{eq}	equivalent damping ratio
K_d	post-yield stiffness (tangential stiffness after yielding of lead plug) of lead rubber bearing
K_{eff}	effective stiffness of an isolator unit in the horizontal direction at either the Design Earthquake or the Maximum Earthquake level (from seismic code)
K_h	shear stiffness
L_L	live load of building-superstructure
P_0	design compressive force in absence of seismic action effects
P_{max}	maximum compressive force including seismic action effects
P_{min}	minimum compressive force including seismic actions effects
$Q_1(X_1)$	shear force at maximum positive shear displacement
$Q_2(X_2)$	shear force at minimum negative shear displacement
Q_d	characteristic strength
S_1	first shape factor
S_2	second shape factor
T_r	total rubber thickness, given by $T_r = n \times t_r$
X_0	design shear displacement
X_1	maximum positive shear displacement
X_2	minimum negative shear displacement
β_{eff}	effective damping (equivalent viscous damping ratio) of an isolator unit in the horizontal direction at either the Design Earthquake or the Maximum Earthquake level (from seismic code)
γ_0	design shear strain
γ_{max}	maximum design shear strain during earthquake
γ_u	ultimate shear strain under horizontal uniaxial loading
σ_0	design compressive stress
σ_{max}	maximum compressive stress
σ_{min}	minimum compressive stress

[a] The terms “Design Earthquake” and “Maximum Earthquake” are used for simplicity herein to facilitate explanation of concepts and relationships for two earthquake hazard levels. It is recognized that these terms are not directly used by ASCE 7-22 or other building codes. The test parameters presented in subsequent tables (give table numbers) assume that the Design Earthquake demand is 2/3 of the Maximum Earthquake Demand.

5 Structure of ISO 22762 from perspective of relationship with this document

The relationship between the different parts of ISO 22762 is shown schematically in Figure 2. This document intends to help structural engineers whereas ISO 22762-4 helps manufacturers of elastomeric isolators for buildings.

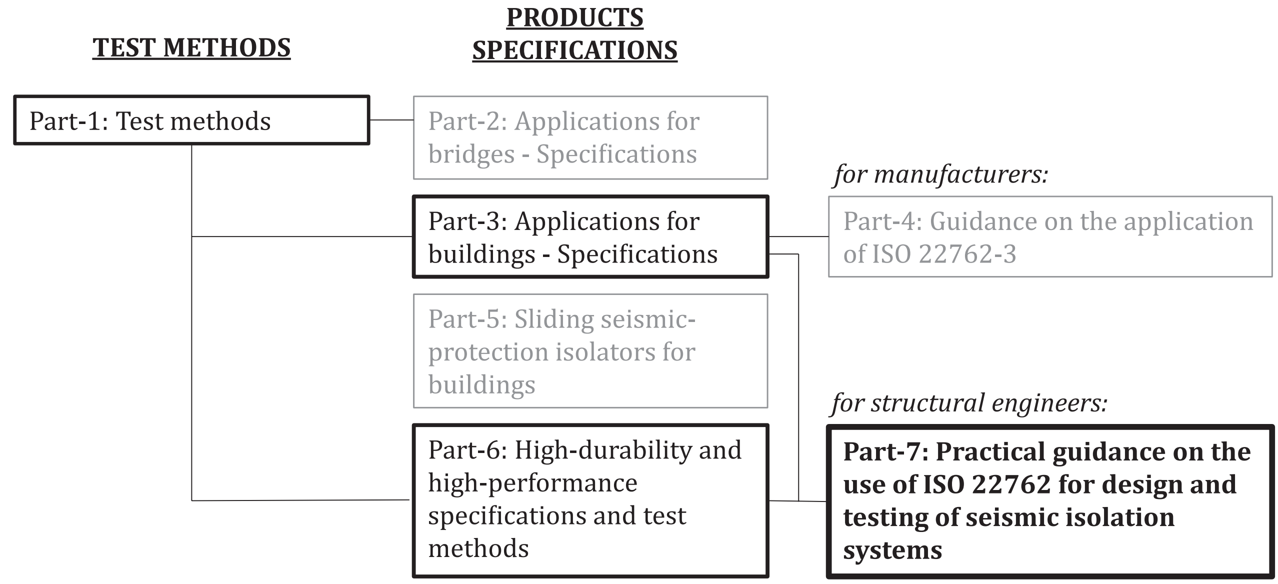

Figure 2 — Relationship of this document and other parts of the ISO 22762 series

6 Application of ISO 22762 to the testing and design requirements of elastomeric isolators given in building codes

6.1 General

When applying the ISO 22762 series for the design of elastomeric seismic isolation bearings it is necessary for the user to relate various design terms and symbols in the seismic code or guideline being followed with the applicable terms and symbols in ISO 22762 series. It is expected that the main users of ISO 22762 series will be structural engineers and that their primary interest will be the testing requirements for the seismic isolators. The types of tests typically required are qualification tests, prototype tests and production tests.

6.2 Correspondence between seismic codes and ISO 22762: Key design terms and definitions

The correspondence between key design terms and definitions commonly used in seismic codes and those used in ISO 22762 series is shown in Table 2.

Table 2 — Correspondence between seismic codes and ISO 22762: Key design terms and definitions

Seismic code term	ISO 22762 term	Remarks
Qualification test	Type test	All tests and requirements specified in ISO 22762-3 or ISO 22762-6 are applicable.
Prototype test	Type test	There are minor differences in some definitions of isolator properties between seismic codes and ISO 22762. In such case, similar definition in ISO 22762 is applied.
Production test	Routine test	Some minor differences exist in definition of the properties. In such case, similar definition in ISO 22762 is applied.

Table 2 *(continued)*

Seismic code term		ISO 22762 term	Remarks
Vertical load	$1{,}0\ D_L + 0{,}5\ L_L$	Design compressive force P_0	Design compressive stress $\sigma_0 = P_0/A$
	$1{,}2\ D_L + L_L + E_L$	Maximum compressive force P_{max}	Maximum compressive stress $\sigma_{max} = P_{max}/\ A$
	$0{,}9\ D_L - E_L$	Minimum compressive force P_{min} (if negative) Tensile force $P_t = P_{min}$	Minimum compressive stress $\sigma_{min} = P_{min}/\ A$
Horizontal displacement	D_D	Design displacement X_0	Design shear strain $\gamma_0 = X_0/T_r$
	D_M, D_{TM}	Maximum displacement X_{max}	Maximum shear strain $\gamma_{max} = X_{max}/T_r$

6.3 Correspondence between seismic codes and ISO 22762: Testing

6.3.1 Qualification tests

Although most seismic codes do not provide specific details for qualification tests, manufacturers generally must provide structural engineers with various properties of isolators, including dependencies on effects such as temperature and frequency, repeated loading, creep, and ageing. Tests for these properties are specified as type tests of ISO 22762-3 and ISO 22762-6 using test methods defined in ISO 22762-1. These tests and methods are directly applicable for manufacturers to provide qualification test data for elastomeric isolators. ISO 22762 provisions to be able to refer for qualification test of elastomeric isolators are shown in Table 3. Comparison of the test items and requirements in EN 15129 and ISO 22762-6 are given in Annex A.

Table 3 — ISO 22762 provisions for qualification tests of elastomeric isolators

Properties	Test item	Test method
Compressive properties	Compressive stiffness	ISO 22762-1:2018, 6.2.1, method 2
Shear properties	Shear stiffness Equivalent damping ratio Post-yield stiffness (for LRB) Characteristic strength (for LRB)	ISO 22762-1:2018, 6.2.2
Tensile properties	Tensile fracture strength Tensile yield strength	ISO 22762-1:2018, 6.5
Dependencies of shear properties	Shear strain dependency	ISO 22762-1:2018, 6.3.1
	Compressive stress dependency	ISO 22762-1:2018, 6.3.2
	Frequency dependency	ISO 22762-1:2018, 6.3.3
	Repeated loading dependency	ISO 22762-1:2018, 6.3.4
	Temperature dependency	ISO 22762-1:2018, 6.3.5
Dependencies of compressive properties	Shear strain dependency	ISO 22762-1:2018, 6.3.6
	Compressive stress dependency	ISO 22762-1:2018, 6.3.7
Shear strain and displacement capacity	Breaking strain, buckling strain Roll-out strain	ISO 22762-1:2018, 6.4

Table 3 *(continued)*

Properties	Test item	Test method
	Ultimate property diagram	ISO 22762-3:2018, Annex B
Durability	Shear property change	ISO 22762-1:2018, 6.6.1
	Creep	ISO 22762-1:2018, 6.6.2

6.3.2 Prototype tests

The correspondence between isolator prototype tests typically defined by seismic codes and the elastomeric isolator test methods of ISO 22762-1 is shown in Table 4. In the table, the seismic code prototype test requirements are those of ASCE 7-22 and TBEC 2018. ISO 22762-3 does not give detailed, specific requirements for each test item, whereas ISO 22762-6 does give specific test requirements, depending on the grade of the isolator.

Table 4 — Correspondence between seismic codes and ISO 22762: prototype tests

Seismic code prototype test condition					ISO 22762 test method and requirements	
Test item	**Test no.**	**Vertical load combination**	**Horizontal displacement**	**Cycles**	**Test method(s)**	**ISO 22762-6:2022 requirements** [a]
Compressive properties	**1**	1,4 D_L +1,6 L_L	0	-	ISO 22762-1:2018, 6.2.1 method 2	Table 6
Shear properties	**2**	D_L + 0,5 L_L	wind force	20	Horizontal shear creep test and residual displacement ISO 22762-6:2022, 8.5.2	No requirement
	3	D_L + 0,5 L_L 1,2 D_L+ 0,5 L_L ± E_L 0,9 D_L ± E_L	0,25 *DD* or 0,25 *DM*	3	Shear strain dependency, ISO 22762-1:2018, 6.3.1	No requirement
			0,5 *DD* or 0,5 *DM*	3		
			0,67 *DD* or 0,67 *DM*	3		
			1,0 *DD* or 1,0 *DM*	3		
	4	D_L + 0,5 L_L	1,00 D_{TD}	10	Repeated loading dependency ISO 22762-1:2018, 6.3.4, ISO 22762-6:2022, 8.2.1	K_d: ≥-10 %, Q_d: ≥-30 %
	5	1,2 D_L +L_L ± E_L	1,00 D_{TM}	1	Shear strain and displacement capacity ISO 22762-1:2018, 6.4	Buckling strain ≥2/3×100×S_2 (%) Breaking strain ≥400 % or Shear displacement capacity: Buckling and breaking displacement ≥ 1,5 X_{max}

[a] In ISO 22762-6, detailed test requirements are defined according to the isolator performance grade. In this table, the ISO 22762-6 test requirements for LRB Grade-II isolators are shown as an example. Examples of the results of the prototype tests in this table are given in Annex B.

Table 4 *(continued)*

Seismic code prototype test condition					ISO 22762 test method and requirements	
Test item	**Test no.**	**Vertical load combination**	**Horizontal displacement**	**Cycles**	**Test method(s)**	**ISO 22762-6:2022 requirements** [a]
	6	0,9 D_L ± E_L	1,00 D_{TM}	1	Tensile capacity ISO 22762-1:2018, 6.5, ISO 22762-6:2022, 8.4.4	≧50 %
[a] In ISO 22762-6, detailed test requirements are defined according to the isolator performance grade. In this table, the ISO 22762-6 test requirements for LRB Grade-II isolators are shown as an example. Examples of the results of the prototype tests in this table are given in Annex B.						

6.3.3 Production tests

Correspondence of test methods specified in ISO 22762-1 for production test which is given in Table 4. Generally, there is no specific method of compression test in seismic codes or guidelines. Therefore, compression test is introduced in Table 5. In ISO 22762-6, the tolerance on compressive and shear properties is classified. As an example, classification of LRB is introduced in Table 6. Grade I in ISO 22762-6 corresponds to the tolerance specified in ISO 22762-3.

Table 5 — Correspondence between seismic codes and ISO 22762-6: Production tests

Seismic code production test condition (ASCE/SEI 7-22)					ISO 22762 test method and requirements	
Test item	**Test no.**	**Vertical load combination**	**Horizontal displacement**	**Cycles**	**Test method**	**ISO 22762-6 Requirements (specifications)**[a]
Shear properties	**1**	D_L + 0,5 L_L	D_D	3	ISO 22762-1:2018, 6.2.2	Table 6
Compressive properties	**2**	—	—	—	ISO 22762-1:2018, 6.2.1 method 2	Table 6
[a] In ISO 22762-6, detailed test requirements are defined according to the islolator performance grade. Requirements for some of test items are specified according to the grade of isolator requirements. In this table, the ISO 22762-6 test requirements for LRB Grade-II isolators are shown as an example.						

Table 6 — Classification by tolerance on compressive and shear properties of LRB in ISO 22762-6

Grade	Compressive stiffness K_v	Shear stiffness K_d, characteristic strength Q_d
I	±30 %	±20 %
II	±20 %	±15 %
III	±15 %	±10 %

6.4 Determination of property modification factors

Property modification factors are used by seismic codes to account for variations in isolation devices properties due to effects such as heating due to dynamic loading, rate of loading, manufacturing variability, temperature, environmental exposure and ageing (for example, ASCE/SEI 7-22, 17.2.8.4). These factors are incorporated in the building seismic response analyses, either by equivalent lateral force procedures or by time history analysis. Property modification factors may be determined by test methods defined in ISO 22762-1. Manufacturing tolerance corresponds to the tolerance on shear properties as specified in ISO 22762-3:2018, 6.5.3.1, Table 6. The relationship between various property modification factors, but not including cyclic effects, and ISO 22762 test methods is given in Table 7.

Table 7 — Use of ISO 22762 for determination of seismic code property modification factors

Seismic code property modification factors (ASCE/SEI 7-22)		ISO 22762 properties and test methods	
		Property	Test methods and standard values
Ageing	λ_a	Property change	ISO 22762-1:2018, 6.6.1 ISO 22762-6:2022, 6.5.1 Tables 4, 5, and 6
Temperature	λ_t	Temperature dependency	ISO 22762-1:2018, 6.3.5 or 5.8 ISO 22762-6:2022, 6.5.1
All cyclic effects	λ_{test}	Repeated loading dependency	ISO 22762-1:2018, 6.3.4 ISO 22762-6:2022, 6.5.1 Tables 4, 5, and 6
Manufacturing tolerance*	λ_{spec}	Shear stiffness Equivalent damping ratio post-yield stiffness (LRB) Characteristic strength (LRB)	ISO 22762-1:2018, 6.2.2 ISO 22762-3:2018, 5.3 Table 3 ISO 22762-6:2022, 6.5.1 Tables 4, 5, and 6
Total in ASCE 7-22	λ_{total}	$\lambda_{total.max}=\lambda_{spec}\times(1+(0,75\times(\lambda_a\lambda_t-1)))\times\lambda_{test}$ $\lambda_{total.min}=\lambda_{spec}\times(1-(0,75\times(\lambda_a\lambda_t-1)))\times\lambda_{test}$	

Cyclic loading effects on isolator properties, according to seismic codes, are evaluated in ISO 22762-1 and ISO 22762-6 by repeated loading dependency tests.

For the manufacturing tolerances listed in Table 7, the tolerances on compressive and shear properties indicated in Table 6 are applicable. Examples of tests and results to evaluate the property variations outlined in Table 7 above are given in Annex C.

6.5 Differences in property definitions between seismic codes and ISO 22762

There are some differences in the definitions of isolator shear stiffness and damping properties between seismic codes and ISO 22762. These are shown in Table 8. Annex D provides example HDR test results along with evaluation of shear and damping properties using the two different definitions.

Table 8 — Seismic code and ISO 22762 shear stiffness and damping property definitions

Property	Seismic codes	ISO 22762-1:2018, 6.2.2.6
Shear stiffness	$K_{eff}=\dfrac{Q_1(X_1)-Q_2(X_2)}{X_1-X_2}$	$K_h=\dfrac{Q_1-Q_2}{X_1-X_2}$
	$Q_1(X_1)-Q_2(X_2)$: shear force at $X1$, $X2$ $X1$, $X2$: maximum, minimum shear displacement	$Q1$, $Q2$: maximum, minimum shear force $X1$, $X2$: maximum, minimum shear displacement
	Calculation: Average of 1st to 3rd loops	Calculation: from 3rd loop
Equivalent damping ratio	$\beta_{eff}=\dfrac{\pi}{2}\dfrac{W_d}{K_{eff}(X_1-X_2)^2}$	$H_{eq}=\dfrac{\pi}{2}\dfrac{W_d}{K_h(X_1-X_2)^2}$
	Calculation: Average of 1st to 3rd loops	Calculation: from 3rd loop