भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
BUREAU OF INDIAN STANDARDS
(Ministry of Consumer Affairs, Food & Public Distribution, Govt. of India)

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व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 39/टी- 27 **28 अप्रैल 2025**

तकनीकी समिति : भूकंप इंजीनियरिंग अनुभागीय समिति , सीईडी 39

प्राप्तकर्ता :

1. **सिविल अभियांत्रिकी विभाग परिषद, सीईडीसी के सभी सदस्य**
2. **भूकंप इंजीनियरिंग अनुभागीय समिति, सीईडी 39**
3. **सीईडी 39 की उपसमितियों और अन्य कार्यदल के सभी सदस्य**
4. **रुचि रखने वाले अन्य निकाय।**

महोदय/महोदया,

निम्नलिखित मानक का मसौदा संलग्न है:

प्रलेख संख्या	शीर्षक
सीईडी 39(27937)WC	**संरचनाओं के भूकंप प्रतिरोधी डिज़ाइन के लिए मानदंड भाग 6 भूकंपीय दृष्टि से आइसोलेटेड भवनों** [IS 1893 (*भाग* 6) *का पहला पुनरीक्षण*] का भारतीय मानक मसौदा आई सी एस संख्या : 91.120.25

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजे कि यह मसौदा प्रकाशित हो तो इन पर अमल करने में आपको व्यवसाय अथवा कारोबार में क्या कठिनाइयां आ सकती हैं।

सम्मतियाँ भेजने की अंतिम तिथि: 28 मई 2025

सम्मति यदि कोई हो तो कृपया अधोहस्ताक्षरी को ई-मेल द्वारा **ced39@bis.gov.in** पर या उपरलिखित पते पर, संलग्न फोर्मेट में भेजें। सम्मतियाँ बीआईएस ई-गवर्नेंस पोर्टल, **www.manakonline.in** के माध्यम से ऑनलाइन भी भेजी जा सकती हैं।

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संलग्न: उपरलिखित

भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
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WIDE CIRCULATION DRAFT

Our Reference: CED 39/T- 27 **28 April 2025**

TECHNICAL COMMITTEE: EARTHQUAKE ENGINEERING SECTIONAL COMMITTEE, CED 39
ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of Earthquake Engineering Sectional Committee, CED 39
3. All Members of Subcommittees, Panels and Working Groups under CED 39
4. All others interested.

Dear Sir/Madam,
Please find enclosed the following draft:

Doc No.	Title
CED 39(27937)WC	**Draft Indian Standard Criteria for Earthquake Resistant Design of Structures** **Part 6 Base Isolated Buildings** [*First Revision* of IS 1893 (Part 6)] ICS No. 91.120.25

Kindly examine the attached draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard.

Last Date for comments: 28 May 2025

Comments if any, may please be made in the enclosed format and emailed at ced39@bis.gov.in or sent at the above address. Additionally, comments may be sent online through the BIS e-governance portal, www.manakonline.in.

In case no comments are received or comments received are of editorial nature, kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website www.bis.gov.in.

Thanking you,

Yours faithfully,
Sd/-
Dwaipayan Bhadra
Scientist 'E' & Head
Civil Engineering Department

Encl: As above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. Comments through e-mail to ced39@bis.gov.in shall be appreciated.]

Doc. No.: CED 39 (27937)WC

BIS Letter Ref: CED 39/T- 27

Title: Draft Indian Standard Criteria for Earthquake Resistant Design of Structures Part 6 Base Isolated Buildings [*First Revision* of IS 1893 (Part 6)] ICS No. 91.120.25

Last date of comments: 28 May 2025

Name of the Commentator/ Organization:

____

Sl No.	Clause/ Para/ Table/ Figure No. commented	Type of Comment (General/ Technical/ Editorial)	Comments/ Modified Wordings	Justification of Proposed Change

NOTE- *Kindly insert more rows as necessary for each clause/table, etc*

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DRAFT STANDARD FOR COMMENTS ONLY

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Draft Indian Standard

Criteria for Earthquake Resistant Design of Structures

Part 6 Base Isolated Buildings

[*First Revision* of IS 1893 (Part 6)]

ICS No. 91.120.25

Earthquake Engineering	Last Date for Comments:
Sectional Committee, CED 39	**28 May 2025**

Earthquake Engineering Sectional Committee, CED 39

FOREWORD

[*Formal clause will be added later*]

Large part of the Indian landmass is prone to moderate to severe earthquake shaking, and there are many critical structures built in these areas. Hence, earthquake resistant design is essential. In contrast to conventional approach of earthquake resistant design, wherein damage is expected in select structural members, this standard attempts to reduce the extent of damage in base isolated buildings. Unless stated otherwise, provisions of this standard are to be read necessarily in conjunction with the general provisions as laid down in IS 1893 (Part 1).

This standard was first published in 2022. In order to harmonize the standard with the revised earthquake hazard and earthquake zone map of India given in IS 1893 (Part 1), the Committee decided to revise the provisions of this standard.

This standard IS 1893 (Part 6) covers the requirements of base isolated buildings, or portions thereof, which shall be designed and constructed to mitigate the effects of earthquake induced displacements and forces. The provisions of this standard are applicable only to RC buildings and steel frame buildings, as covered by Table 5 of IS 1893 (Part 5) conforming to the configuration requirements as per **5.2** of IS 1893 (Part 5), and not to buildings with precast elements based lateral load systems. The standard provides guidelines for estimation of design lateral force and displacement to be considered in the design of buildings with base isolation system, method of structural analysis to be adopted in the analysis of such buildings, and guidelines for testing of the seismic isolation devices that are used in such buildings. The underlying philosophy of this standard is that a base isolated building will perform better than a conventional building (with fixed base) when subjected to moderate to severe earthquake shaking. It is not the intent of this standard to reduce the construction cost, but it attempts to minimize damage to base isolated buildings and their contents and enhance the likelihood of continued functionality of the building. Generally, it has been observed that base isolation system is more effective for buildings with following conditions:

a) stiff superstructure,
b) rigid foundation on stiff and competent soil,
c) certain ground motions that do not have sharp pulse-like motions, and
d) ductile detailing of the whole structure.

In this revision, the design provisions have been harmonized with design earthquake hazard given in IS 1893 (Part 1) and with the provisions given in IS 1893 (Part 5).

For identifying and ascertaining the proximity of the site of a base isolated building to an active or potentially active fault, reference may be made for geo-scientific data to the *Bhukosh gateway* of the Geological Survey of India. For buildings within 20 km of an active fault, site-specific spectra shall be developed and used, and the building analysed using specialist literature.

Base Isolated Buildings that are not addressed explicitly by this standard require full dynamic analysis to be carried out to ascertain their likely performance; this standard shall not be used to design such buildings.

This standard IS 1893 (Part 6) may be used also for the design of base isolation system for existing buildings, as part of earthquake retrofitting. In such cases, full dynamic analysis shall be required to ascertain the likely performance.

In the preparation of this standard, assistance has been derived from the following publications:

European Standard EN 15129;
International Building Code IBC 2012
American Society of Civil Engineering ASCE 7(2016);
International Standards Organisation ISO 22762-I;
Federal Emergency Management Agency FEMA 751; and
Japan Notification Nos. 2009 and 1446, Ministry of Land, Infrastructure and Transport, Government of Japan

This standard contributes to the following Sustainable Development Goals:

Goal 9 Industry, Innovation and Infrastructure towards building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation; and
Goal 11 Sustainable Cities and Communities towards making cities and human settlements inclusive, safe, resilient and sustainable.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2: 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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Draft Indian Standard

CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES
PART 6 BASE ISOLATED BUILDINGS

[*First Revision* of IS 1893 (Part 6)]
ICS No. 91.120.25

Earthquake Engineering	Last Date for Comments:
Sectional Committee, CED 39	**28 May 2025**

1 SCOPE

1.1 This standard provides requirements for base isolated buildings, which shall be designed and constructed to resist earthquake induced effects (namely displacements and forces) as specified herein. The provisions of this standard are applicable only to:

a) Conventional monolithic RC buildings and steel frame buildings, excluding those with pure flat slabs or precast elements based lateral load resisting systems, not covered by IS 1893 (Part 5); and
b) Buildings with base-isolation devices, such as elastomeric and sliding systems, all of which are located at the same level only, along the height of the building (and not at multiple levels).

1.2 Buildings with base-isolation devices are expected to perform better than the conventional fixed-base buildings, especially in terms of damage in the structural and non-structural elements in the superstructure above the isolation level.

1.3 The underlying principles of the provisions of this standard are:

a) Base-isolated buildings designed using this standard shall perform better than the corresponding fixed-base buildings when subjected to ground motions expected in the applicable the seismic zone; and
b) The desired sequence of damage is superstructure, isolators, substructure and foundation.

1.4 This standard suggests the estimation of design earthquake lateral forces and displacements to be considered and the method of structural analysis to be adopted, in the design of buildings with base isolation systems, and the specifications and method of testing of the base isolators that are proposed to be used in such buildings.

2 REFERENCES

The standards listed in Annex A contain provisions which, through reference in this standard, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed in Annex A.

3 TERMINOLOGY

For the purpose of this standard, the terms shall have the meaning as mentioned below:

3.1 Base Level — The top level of the base isolators placed in the building.

3.2 Base Isolation System — The collection of special elements, including all individual isolators and their connections to the adjoining structural elements, which transfer forces due to gravity and forces induced during earthquake shaking, between the structural elements of the building above and below the base-isolation system.

3.3 Base Isolator — The horizontally flexible and vertically stiff structural element of the Base-Isolation System provided in the building, which is designed to permit a specified value of lateral displacement at the base of the building during earthquake shaking, and to dissipate energy under cyclic loading.

3.4 Design Displacement — The lateral displacement, excluding additional displacement due to actual and accidental torsion, to be considered in the design of the base-Isolation system (or one of its isolators thereof) of a building to resist earthquake shaking.

3.5 Effective Damping — The equivalent viscous damping (as percentage of critical damping) of the base-isolator, obtained from its experimental characteristic cyclic loop at the amplitude of interest, which is considered in design of the base-isolator.

3.6 Effective Stiffness — The secant stiffness of the characteristic cyclic loop of the base-isolator at the amplitude of interest, which is considered in design of the base-isolator.

3.7 Load Transfer System — The collection of all structural elements through which the loads (namely axial forces, shear forces, bending moments and torsional moments) flow, which are generated by gravity, earthquake shaking or other load effects on the building. These include segments of columns and connecting beams above the base isolation system.

3.8 Total Design Displacement — The lateral displacement, plus additional displacement due to actual and accidental torsion, to be considered in the design of the base-Isolation system (or one of its isolators thereof) of a building to resist earthquake shaking.

4 SYMBOLS

For the purpose of this standard, the following letter symbols shall have the meaning indicated against each:

A_g	Gross cross-section area
A_{NH}	Normalised elastic maximum PSA of a equivalent fixed-bases superstructure corresponding to the effective natural period T_{eff} as per **6.2** of IS 1893 (Part 1)
B	Plan dimension of the building, above the base level, perpendicular to the considered direction of earthquake shaking
D	Plan dimension of the building, above the base level, along the considered direction of earthquake shaking
DL	Dead Load on the building as per IS 875 (Part 1)
EL	Design Earthquake Load as per IS 1893 (Part 1 and Part 5), unless otherwise specified in this standard
e	Actual eccentricity measured in plan between the Centre of Mass of the building above the base level and the Centre of Resistance of the Base-Isolation System, plus accidental eccentricity (5 percent of the maximum building dimension perpendicular to the considered direction of earthquake shaking)
F^{+}_{max}	Force in a base-isolator unit in the forward direction along the considered direction of earthquake shaking, during a single cycle of prototype testing, at a displacement amplitude of Δ^{+}_{max}
F^{-}_{max}	Force in a base-isolator unit in the backward direction along the considered direction of earthquake shaking, during a single cycle of prototype testing, at a displacement amplitude of Δ^{-}_{max}
h_i	Height of floor *i* from the base level
I	Importance factor to be used in the estimation of design earthquake lateral force of the building, as given in Table 7 of IS 1893 (Part 5)
I_g	Gross moment of inertia of a section
$K_{eff,max}$	Maximum effective stiffness of the base-isolation system at the design displacement along the considered direction of earthquake shaking
$K_{eff,min}$	Minimum effective stiffness of the base-isolation system at the design displacement along the considered direction of earthquake shaking
$k_{initial}$	Initial stiffness of the base-isolator along the considered direction of earthquake shaking
$k_{eff,max}$	Maximum effective stiffness of the base-isolator estimated along the considered direction of earthquake shaking, in a single cycle during prototype testing of the base-isolator out of the first three repeated cycles of loading in the design displacement range $[-\Delta_{ID}, +\Delta_{ID}]$ of the base isolator
$k_{eff,min}$	Minimum effective stiffness of the *base-isolator* estimated along the considered direction of earthquake shaking, in a single cycle during prototype testing of the base-isolator out of the first three repeated cycles of loading in the design displacement range $[-\Delta_{ID}, +\Delta_{ID}]$ of the base isolator

IL	Imposed load on the building as per IS 875 (Part 2)
Q_{i}	Design floor lateral forces to be applied at floor level *i* of the building above the base level
R	Elastic force reduction factor of a fixed base building
R_{I}	Elastic force reduction factor of a base-isolated building
$\left(\frac{S_{\mathrm{a}}}{g}\right)_{T_{\mathrm{eff}}}$	Design horizontal spectral acceleration coefficient (corresponding to 5 percent damping) at a natural period of T_{eff} **,** as obtained from IS 1893 (Part 1)
T	Fundamental lateral translational natural period (in s) of the fixed-base building (without a base isolation system)
T_{eff}	Effective natural period (in s) estimated of base-isolated building at the design displacement in the considered direction of earthquake shaking
$T_{\mathrm{eff,max}}$	Maximum value of effective natural period (in s) T_{eff} obtained from experiments of the Base-isolated building at the design displacement in the considered direction of earthquake shaking
$T_{\mathrm{eff,min}}$	Minimum value of effective natural period (in s) T_{eff} obtained from experiments of the Base-isolated building at the design displacement in the considered direction of earthquake shaking
T_{s}	Site period is the fundamental natural period of the site for shaking in the horizontal direction
V_{B}	Design earthquake lateral force to be used in the design of the structural elements below the base-isolation system in the direction of shaking
V_{S}	Design earthquake lateral force to be used in the design of the structural elements above the base-isolation system in the direction of shaking
$V_{S}^{\mathrm{e,max}}$	Elastic maximum base shear without using the response reduction factor
$V_{\mathrm{S,min}}$	Minimum earthquake lateral force to be used in the design of the structural elements above the base-isolation system in the direction of shaking
W_{i}	Effective seismic weight of floor *i* of the building above the base isolation system
W_{j}	Effective seismic weight of floor *j* of the building above the base isolation system
W'	Effective seismic weight of the building above the base isolation system
Y	Distance between the centre of resistance of the all base-isolators together and location of the base isolator in focus, measured perpendicular to the considered direction of earthquake shaking
Z	Earthquake zone factor, as given in Table 3 of IS 1893 (Part 1)
β	Multiplier to be applied on 5 percent damping, corresponding to effective damping of the base-isolator in focus
β_{eff}	Effective damping in the base-Isolation system at the design displacement
$\beta_{\mathrm{eff}}^{\mathrm{i}}$	Effective damping in the base-isolator *i* estimated through prototype testing of the base-isolator
Δ_{ID}	Design displacement of a base-isolator unit, including both translational displacement at the centre of resistance, and the component of torsional displacement in the considered direction of earthquake shaking
$\Delta_{\mathrm{max}}^{+}$	Maximum displacement in a base-isolator in the forward direction along the considered direction of earthquake shaking, in a single cycle during prototype testing of the base-isolator

$\Delta^{-}_{\max}$	Maximum displacement in a base-isolator in the backward direction along the considered direction of earthquake shaking, in a single cycle during prototype testing of the base-isolator
Δ_{SD}	Design displacement of the base-Isolation system at the center of resistance in the considered direction of earthquake shaking

When other symbols are used, they are explained at the appropriate place.

5 GENERAL REQUIREMENTS

The base-isolation system employed shall:

a) be stable at the total design displacement,
b) offer increased resistance with increase in displacement,
c) not sustain significant degradation of its properties under repeated cyclic loading, and
d) possess well-established and reproducible engineering properties (namely effective stiffness and damping).

Items (c) and (d) above shall be in accordance with requirements given under **7**.

A base-isolated building shall be designed considering seismic zone, site characteristics, vertical acceleration, gross cross-section properties, occupancy, configuration, structural system and height in accordance with clauses provided for the same in IS 1893 (Part 1 and Part 5).

In general, base isolated buildings should be located at sites that have Site Classes A, B and C as classified in IS 1893 (Part 1). Also, even within sites with Site Classes A, B and C, sites that are liquifiable shall not be chosen for constructing base-isolated buildings.

All base isolated buildings shall be provided with ductile detailing as per the requirements for special moment frames and/or special structural walls of IS 13920 (Part 5) for reinforced concrete building, and as per the requirements of special moment frames (SMRF), special concentrically braced frames (SCBF) and/or eccentrically braced frame (EBF) of IS 18168 for structural steel buildings.

5.1 Elements of a Base-isolated Building

The design requirements of this Standard distinguish between the three sub-systems of a base isolated building (Fig. 1):

a) Superstructure, which includes elements of the structure above the base level;
b) Base-isolation system, which includes all individual base isolators and their connection elements; and
c) Substructure, which includes structural elements of the structure below the base level, namely-foundation structural elements and the soil in contact with the foundation and beyond it up to a depth and width beyond the foundation structural elements as per acceptable principles of soil mechanics and structural dynamics.

All base isolator units shall be firmly anchored to the substructure and the superstructure. The forces in the connecting elements shall not exceed its design strength as per IS 800, IS 456 and IS 13920 (Part 5).

5.2 Stability of the Base Isolation System

The stability of the base-isolators (under the expected maximum vertical loads) shall be verified by both structural analysis and cyclic testing (as per **7.1**), at the total design lateral displacement. A base-isolator is said to be in uplift condition, if it develops tensile force in the axial vertical direction under any load combination.

In general, no tensile load shall be permitted in any base isolation device. In case of tensile loading in elastomeric base isolators, the maximum tensile stress in the base isolator should not exceed G (shear modulus of the base isolator). Whether or not uplift is likely to occur in base isolated buildings with any type of base isolator system response history analysis shall be performed (including the effect of vertical earthquake ground shaking).

Under the load combinations that involve earthquake load effects, the factor of safety against overturning at the base of the substructure, shall be at least 1.4 and that against sliding at least 1.2. For the purposes of the estimation of the above factors of safety, the earthquake load effects in the superstructure shall be estimated using elastic maximum base shear without using the elastic force reduction factor *R* [as per Table 5 of IS 1893 (Part 5)] as given by:

$$V_{\mathrm{BD}}^{\mathrm{e,\ max}} = ZIA_{\mathrm{NH}}\left(\frac{W'}{g}\right)$$

where,

Z	=	Earthquake zone factor, as given in Table 3 of IS 1893 (Part 1)
I	=	Importance factor of the building
A_{NH}	=	Normalised elastic maximum PSA of an equivalent fixed-bases superstructure corresponding to the effective natural period T_{eff} as per **6.2** of IS 1893 (Part 1)
W'	=	Effective seismic weight of the building above the base isolation system

5.3 Configuration Requirements

The structural configuration of a base-isolated building shall be assessed to be regular or irregular based on of the portion of the building above the base-isolation system, in accordance with the provisions of IS 1893 (Part 5). The provisions of this standard shall be applicable only for base-isolated buildings that are regular as per IS 1893 (Part 5). In addition, the in-plan placement of the base isolators shall be such that their centre of resistance along two horizontal plan directions shall coincide with the centre of resistances of the substructure as well as the super-structure.

5.4 Residual Displacement

Base-Isolated building are expected to experience displacement during earthquake events and may sustain residual displacement at the level of isolator. Services and utilities that cross the isolation interface shall be designed and detailed to accommodate the total displacement without disruption in their functionality.

5.5 Separation from the Adjacent Building and Location of Moat

The wall of the moat of a base isolated building shall be placed at a distance not less than the total design displacement Δ_{ID} of the base-isolator units as estimated in **6.1.4**.

For base isolated buildings that are adjacent to each other, the minimum clear distance between the buildings will be equal to the sum of the design displacement and two times to the total lateral displacement of each building, as estimated in **6.1.8**.

A base isolated building shall be separated from an adjacent building (base-isolated or otherwise) by a distance at least equal to the design displacement Δ_{ID} (as estimated in **6.1.4**) plus the separation distance specified in **5.2.3** of IS 1893 (Part 5).

5.6 Design Acceleration Spectrum

The design acceleration spectral value of the base-isolated building shall be taken corresponding to the design earthquake hazard as per **6.2** of IS 1893 (Part 1).

5.7 Location of Base Isolators

All base isolators in a building shall be placed at a single level such that their top levels are in the same horizontal plane. When isolators are placed on column stubs, the maximum height of the column stubs below the isolators shall not be more than 2.5 m. Also:

a) All lift shafts, stair wells and specialist equipment which require to be with the superstructure, shall be suspended from the superstructure, even though crossing below the isolation plane; and
b) All flexible elements crossing the isolation plane from the substructure to the superstructure shall be detailed to comply with the relative deformation imposed at the isolation plane.

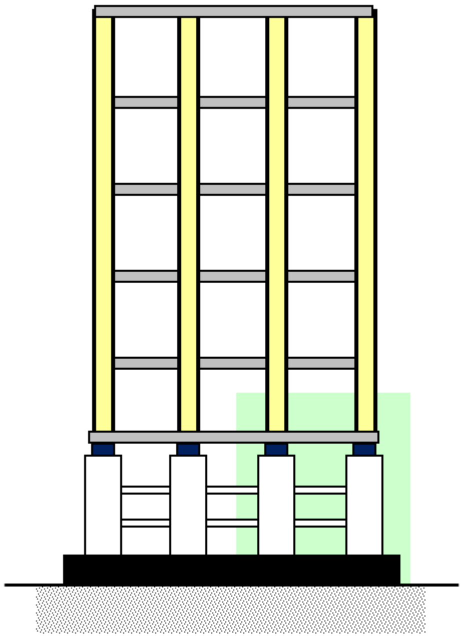
All base isolator units shall be placed such that there is adequate space for inspection-related movement, both during installation and later for replacement. Necessary provisions shall be incorporated in the general design of the building to ensure that there is no possibility of damage to the base isolator units due to exposure to fire, flooding or freezing, as the case may be.

5.8 Structural Systems

The structural systems and the corresponding elastic force reduction factor admissible to resist effects of earthquake shaking when they are to be used with base-isolation are given in Table 1.

Table 1 Elastic Force Reduction Factor *R* for Structural Systems admissible to be used for Building with Base-Isolation
[*Clause* 5.8]

Sl No.	Structural System	*R*
(1)	(2)	(3)
i)	**Buildings with braced frames**	
	a) Steel buildings with special concentrically braced frames (SCBFs) designed and detailed as per IS 13920 (Part 5)	4.5
	b) Steel buildings with eccentrically braced frames (EBFs) designed and detailed as per IS 13920 (Part 5)	5.0
ii)	**Buildings with structural walls**	
	a) Reinforced concrete buildings with	
	i) Special RC structural walls without boundary elements (SSWs-RC-NBE) designed and detailed as per IS 13920 (Part 5)	4.5
	ii) Special RC structural walls with boundary elements (SSWs-RC-BE) designed and detailed as per IS 13920 (Part 5)	5.0
iii)	b) Reinforced concrete buildings with moment frames and structural walls	
	i) SSWs-RC-NBE and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	4.0
	ii) SSWs-RC-BE (single SW, or coupled SW) and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	4.5
iv)	**Reinforced concrete buildings with dual structural system (see 7.1.8)**	
	SSWs-RC-BE and SMRFs-RC both designed and detailed as per IS 13920 (Part 5)	5.0



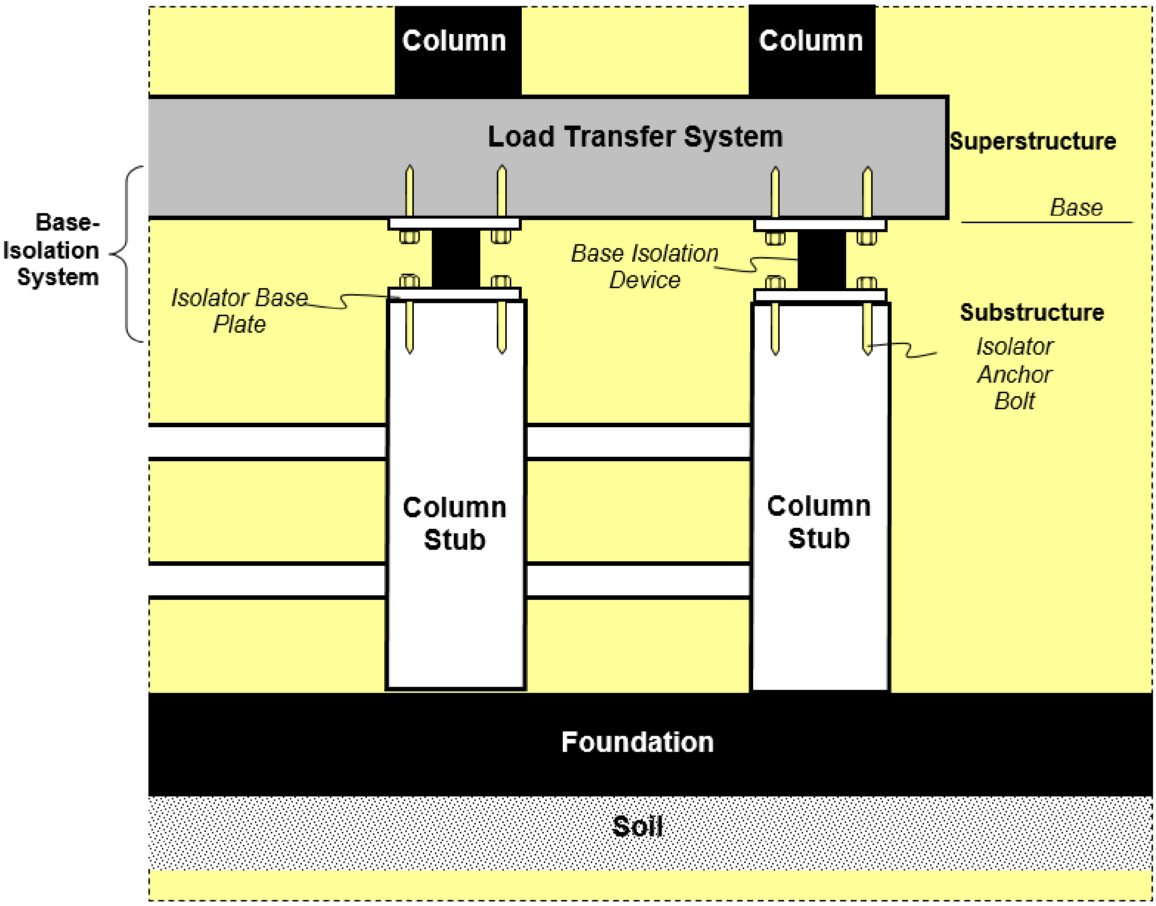


FIG. 1 SECTIONAL ELEVATION OF A BASE ISOLATED BUILDING

6 METHODS OF ANALYSIS

Two linear structural analysis methods may be employed for structural analysis of base-isolated buildings to arrive at the design lateral displacement and the design lateral force of the isolation system, superstructure and substructure, namely:

a) Equivalent static method, and
b) Response spectrum method.

And, nonlinear response history analysis (or nonlinear time history analysis) may be used for checking the adequacy of the design of the base-isolated buildings, as specified in **7.6.2** of IS 1893 (Part 1). The loads and load effects due to earthquake, and the analytical modelling of the structure shall be as per **7.4** of IS 1893 (Part 1) and **5.2** of IS 1893 (Part 5), and as required by **6.2.1**.

6.1 Equivalent Static Method

The equivalent static method (ESM) also called equivalent lateral force method is a linear static analysis procedure, which uses effective stiffness and effective damping properties in the modelling of base isolators. Here, the first translational mode of the building associated with the horizontal displacement of the base isolation system alone (also known as Isolation mode) is considered. This method assumes most of the lateral displacement to occur in the base isolation system. The method is used for design of superstructure, base-isolation system and substructure of buildings that meet the conditions given in **6.1.1**. The results of this method of analysis stand as the lower-bound limit to the results of response spectrum method (RSM) as per **6.2**, when used.

6.1.1 *Conditions for Use of ESM*

The method can be used for design of Base Isolated Buildings, without performing dynamic analysis to confirm the acceptable behaviour, if the building satisfies all of the following:

a) Not located within 20 km from any known active fault;
b) Resting on Site Classes A, B and C, as per IS 1893 (Part 1);
c) Less than or equal to 20 m in height, above the base level;
d) Has effective natural period T_{eff} equal to or less than 3.0 s;
e) Has Effective Natural Period T_{eff} along a considered direction of shaking more than three times the Fundamental Natural Period T along the same direction of shaking of the corresponding Fixed-Base Building;
f) The base isolation system meets all of the following three criteria:
   1) Its effective stiffness at the design displacement is more than one-third of its effective stiffness at 20 percent of the design displacement;
   2) It is capable of re-centering after the earthquake; and
   3) It possesses Force-Displacement Characteristic independent of the rate of cyclic loading.
g) Located in Seismic Zone II only; and
h) Conforms to configuration regularity criteria as per IS 1893 (Part 5).

6.1.2 *Design Displacement*

The Base-Isolation System shall be designed and constructed to withstand a minimum lateral earthquake displacement of Δ_{SD} along each of its principal plan direction, and estimated by:

$$\Delta_{\mathrm{SD}} = [ZIA_{\mathrm{NH}}]g\frac{T_{\mathrm{eff,\ max}}^{2}}{4\pi^{2}}$$

A_{NH} shall be estimated corresponding to the damping ratio of the base isolation system as per **6.2.4.3** of IS 1893 (Part 1).

6.1.3 *Effective Natural Period of the Base Isolated Building*

The maximum effective natural period $T_{\mathrm{eff,max}}$ and minimum effective natural period $T_{\mathrm{eff,min}}$ of the base-isolated building at the design displacement along each of its principal plan direction shall be determined using its effective minimum stiffness $K_{\mathrm{eff,min}}$ and effective maximum stiffness $K_{\mathrm{eff,max}}$, respectively, of the entire set of the base isolators provided in the building, derived from the hysteretic force-displacement loops of the testing of typical base isolators used, when subjected to cyclic inelastic excursion in the design displacement of $-\Delta_{\mathrm{ID}}$ and $+\Delta_{\mathrm{ID}}$, respectively, of the base isolation system, shall be estimated as:

$$T_{\mathrm{eff,\ max}} = 2\pi\sqrt{\frac{W'}{gK_{\mathrm{eff,\ min}}}} \text{ and } T_{\mathrm{eff,\ min}} = 2\pi\sqrt{\frac{W'}{gK_{\mathrm{eff,\ max}}}}$$

6.1.4 *Total Design Displacement*

A *base-isolator* of the base-isolation system shall be designed to sustain additional displacement owing to actual and accidental torsion arising from the spatial distribution of the lateral stiffness of the base isolators distributed in plan and the most disadvantageous location of mass eccentricity. The base-isolator of a Base-isolated building with uniform spatial distribution of lateral stiffness shall be designed to resist a design displacement Δ_{ID} of the *base isolator* given by:

$$\Delta_{\mathrm{ID}} = \Delta_{\mathrm{SD}}\left[1+\left(\frac{12e}{B^{2}+D^{2}}\right)y\right]$$

Δ_{ID} estimated as above shall not be less than 1.1 times the design displacement Δ_{SD} of the base isolation system specified in **6.1.2**, provided the base-isolation system is shown by analyses to be capable of resisting torsion accordingly.

6.1.5 *Design Earthquake Lateral Force for the Components of the Isolation System and of the Structural Elements below the Base-Isolation System*

The components of the base-isolation system and the structural elements below the Base-Isolation System shall be designed to resist along each principal plan direction, at least for the design earthquake lateral force V_{B} estimated by:

$$V_B = K_{eff,\ max}\Delta_{SD}$$

The maximum inter-storey drift in the substructure shall not exceed 0.001 times the storey height, when subjected to design earthquake lateral force V_B specified above.

6.1.6 *Design Earthquake Base Shear Force of the Superstructure*

The structural elements above the base-isolation system, that is, superstructure, shall be designed to resist design earthquake base shear force V_S along each principal plan direction, which is estimated as:

$$V_s = \frac{V_B}{R_I}$$

Where,

R_I = Elastic force reduction factor of a base-isolated building given by:

$$R_I = Min\left[\frac{3}{4}R\ ;\ 2\right]$$

where *R* is the elastic force reduction factor specified in Table 5 of IS 1893 (Part 5) based on the structural system of the building above the base-isolation system. Ductile detailing is required to be provided in the entire building.

The minimum design lateral force $V_{S,min}$ along each direction of shaking shall not be less than any of the following:

a) The design earthquake base shear force for a fixed-base structure of effective seismic weight *W '* and the period equal to $T_{eff,min}$ of the isolation system, estimated as:

$$V_S = \frac{ZI}{R} A_{NH} \frac{W'}{g}$$

b) The wind base shear force estimated as per IS 875 (Part 3) corresponding to the 1.5 times the design wind load; and
c) 1.5 times the shear force H_A required for activation of the isolation system, estimated as:

$$H_A = \sum_{i=1}^{N_{BI}} \left[\frac{k_{initial,i}\ \Delta_{y,i}}{1 + \left(\frac{12e}{B^2 + D^2}\right) y_i} \right]$$

where,

y_i = Distance between the base isolator *i* and the center of resistance at the level of base isolation, perpendicular to the direction of shaking considered

d) Slip threshold of sliding isolation system.

6.1.7 *Distribution of Design Lateral Force along the Height of the Building above the Base level*

The design floor lateral forces Q_i to be applied at floor level *i* of the building above the base level shall be estimated using the design earthquake base shear force (V_S), by:

$$Q_i = V_S \left[\frac{W_i H_i^2}{\sum_{j=1}^{N+1} \left(W_j H_j^2 \right)} \right]$$

The summation in the above expression shall include the mass of the base slab also at the top of the beam resting on the isolator system (*see* Fig. 1).

6.1.8 *Drift Limits in the Building above the Base Level*

The maximum inter-storey drift in the superstructure shall not exceed 0.001 times the storey height, when subjected to design earthquake lateral force (V_S) specified in **6.1.6**.

6.2 Response Spectrum Method

The response spectrum method is a linear static analysis procedure, which uses effective stiffness and effective damping properties in the modelling of base isolators, and assumes more than one mode of the building to participate in the total response. The number of modes and their combination shall be as per the requirements of IS 1893 (Part 5). The method shall be used for design of both the superstructure and the substructure of buildings that do not meet the conditions given in **6.1.1**. When this method of analysis is employed, the design lateral force as per the equivalent static method given by **6.1** shall stand as a lower bound.

This method of analysis shall be performed using a 3-dimensional model of the complete soil – foundation – base isolation – superstructure system. Even when a building meets the requirements of **6.1** of this standard, the equivalent static method may be used for the design of the base isolated building. Soil shall be modelled for Site Class C as per IS 1893 (Part 1); the modelling of soil is not necessary for Site Classes A and B.

Effects of earthquake shaking shall be considered independently along the three principal orthogonal directions of the building, namely:

a) shaking effect along the plan direction X,
b) shaking effect along the plan direction Y, and
c) shaking effect along the vertical direction Z.

The resultant of the earthquake shaking effect along two mutually orthogonal plan directions and along the vertical directions shall be combined to determine the net design earthquake effect, in line with the requirements of **5.3** of IS 1893 (Part 5), and as per acceptable principles of structural dynamics to estimate their combined effects.

6.2.1 *Modelling of Base-Isolated Building*

6.2.1.1 The structural model of a Base-isolated building to be used in structural analysis, when using this method, shall include four sub-systems of the building, namely:

a) The lateral force resisting system of the portion of the building above the base isolation system,
b) The base-isolation system,
c) The lateral force resisting system of the portion of the building below the base isolation system, and
d) The soil–foundation sub-system, each elaborated as per the provisions of this Standard.

6.2.1.2 The said model shall employ linearized force-displacement characteristics of all structural elements of the four sub-systems of the base isolated building. When employing the response spectrum method for the purpose of design of the base isolated building, the maximum displacement of each floor and design forces and displacements in the elements of the earthquake lateral force resisting system can be calculated using a linear elastic model of the base-isolated building, wherein:

a) All elements of the lateral force resisting system of the building above the base-isolation system are elastic; and
b) Stiffness properties of the nonlinear components of the base isolation system are linearized using the minimum effective stiffness of the base-isolation system (as per **7.2** of this standard) and the remaining elements (foundation and column stub portions) are elastic.
c) Also, it shall include, incorporate and account for:

    1) Linearized Load-displacement characteristic of each base isolator along each of the two mutually orthogonal horizontal directions in plan, which are developed and verified based on prototype test, and including effect of vertical load, and/or the rate of loading, if force-displacement characteristics of all base-isolators are dependent on one or more of these attributes. Effective stiffness shall be used corresponding to the minimum lateral stiffness of the base-isolation system;
    2) Spatial distribution of base Isolators in plan of the building;
    3) Lateral displacement along each of the two mutually orthogonal horizontal directions in plan, and torsion of the building above base-isolation system considering most disadvantageous location of eccentric mass; and
    4) Overturning and uplift forces arising on individual base isolators.

d) Further, the structural analysis shall be performed as per **5.3** of IS 1893 (Part 5), using a modal damping for:

    1) The fundamental mode of the base isolated building in the direction of shaking considered, not greater than the smaller of effective damping of the base-isolation system or 25 percent of critical damping, and

2) The higher modes shall be selected consistent with those appropriate for linear response spectrum analysis of the part of the building above the base-isolation system, assuming it to be a fixed-base building.

e) For reinforced concrete buildings, the area of the members shall be equal to the gross cross-sectional area (A_g), and the moment of inertia shall be 0.7 I_g slabs and beams, and 0.9 I_g for columns and structural walls. For structural steel buildings, area of the members shall be equal to the gross cross-sectional area, and the moment of inertia shall be equal to the gross moment of inertia of the member.

6.2.2 *Lower bound limits on Results of Response Spectrum Method*

To avoid possible under-design using response spectrum method, limits prescribed in Table 1 shall be ensured for various design quantities in terms of those obtained from equivalent static method. The limits specified in Table 2 are essential for buildings located in Seismic Zones III, IV, V and VI, and optional for buildings for buildings located in Seismic Zone II.

Table 2 Lower Bound of Various Quantities Estimated from Response Spectrum Method as a Fraction of those Estimated from Equivalent Static Method
(*Clause* 6.2.2)

Sl No.	Design Parameter	Lower Limit as percentage of value computed using Equivalent Static Method
(1)	(2)	(3)
i)	Design displacement Δ_{SD} of the base isolation system	90
ii)	Total design displacement Δ_{ID} of the individual base isolator	80
iii)	Design force of substructure V_B	90
iv)	Design force of superstructure V_S	80

6.2.3 *Design Earthquake Lateral Force of the Components of the Isolation System*

The base isolation components, column stubs and foundation elements below the base isolation system shall be designed to resist the forces estimated in the superstructure considering the building to be a fixed-base one without any response reduction factor applied in its estimation.

7 TESTING OF BASE-ISOLATORS

The design displacements and forces on a base isolated building shall be based on the force-displacement characteristics of the base isolators to be used in the project. The force-displacement characteristics and damping values of the base isolators used in the design and analysis of base isolated buildings shall be based on full-scale testing of select samples of base isolators. The tests specified herein shall be performed prior to design as prescribed herein; they are meant for establishing and validating the properties used in design of the base-isolation system.

7.1 Prototype Tests

Tests on prototype base isolators shall be performed to estimate the characteristics of the backbone curve of the force-displacement behaviour for use in the design of base isolation system. For the purpose of this standard, quasi-static cyclic tests shall be performed separately on three full-scale specimens of predominant type and of each typical size of a Base Isolator proposed to be used in the building as part of the base isolation system. The quantitative outcome of the test shall be the cyclic force-displacement curve of the test specimen in each cycle of test. In the force-displacement curves obtained for the type and size of a base isolator, a difference in the force values at any displacement shall not be more than ± 15 percent.

Prototype tests on isolators can be performed either using single isolator or two isolators in back-to-back position. For back-to-back testing, the isolators shall be of identical type, size and configuration, and the cyclic force-displacement curve of each of the two isolators shall be extracted considering that the force is shared equally by the two isolators. Each back to back test shall be considered as a single test.

7.1.1 *Testing Protocol*

The following sequence of tests shall be performed for the prescribed number of cycles on a base isolator of the type and size proposed to be used in the project:

a) Vertical load equal to the average dead load plus one-half of the effect due to live load, along with 20 fully reversed cycles of loading at a lateral displacement corresponding to the effect of design wind force;
b) Vertical load equal to the average dead load plus one-half of the effect due to live load, along with 3 fully reversed cycles of loading successively at each of the following increments of displacement: $0.25\Delta_{SD}$, $0.5\Delta_{SD}$ and Δ_{SD} corresponding to the earthquake effect;
c) Vertical load equal to the average dead load plus one-half of the effect due to live load, along with 3 fully reversed cycles at the total design displacement $1.0\Delta_{ID}$ corresponding to the earthquake effect;
d) Vertical load corresponding to the load combination of (1.2 *DL* + 0.5 *IL* +*EL*), along with 3 fully reversed cycles of loading successively at each of the following increments of displacement: $0.25\Delta_{SD}$, $0.5\Delta_{SD}$ and Δ_{SD} corresponding to the earthquake effect; and
e) Vertical load corresponding to load combination of (0.8 *DL* – *EL*), along with 3 fully reversed cycles of loading successively at each of the following increments of displacement: $0.25\Delta_{SD}$, $0.5\Delta_{SD}$ and Δ_{SD} corresponding to the Earthquake Effect. Where *(0.8DL – EL)* results in tensile loading on the base-isolator, the building configuration may be reconsidered to ensure no tensile loading on the base-isolator.

7.1.2 *Maximum and Minimum Vertical Load*

Base Isolators that carry vertical load shall be tested statically for the maximum and minimum vertical loads, at the total maximum displacement. In these tests, the combined vertical loads corresponding to the load case of 1.2*DL* + 1.0*IL* + $|EL|_{max}$ shall be taken as the maximum vertical load, and the combined vertical load corresponding to the load case *of 0.8DL* – $|EL|_{min}$ shall be taken as the minimum vertical load, on any Base Isolator of a common type and size.

7.2 Determination of Force-displacement Characteristics

The concepts of effective stiffness and effective damping are used to define displacement behaviour of base isolators. The force-displacement characteristics of the base-isolation system shall be based on the cyclic load tests of isolator prototypes specified in the **7.1**.

The effective stiffness k_{eff}^{i} for each cycle of the three cycles of loading of base isolator i shall be estimated using (*see* Fig. 2):

$$k_{eff}^{i} = \frac{|F_{max}^{+}|^{i} + |F_{max}^{-}|^{i}}{|\Delta_{max}^{+}|^{i} + |\Delta_{max}^{-}|^{i}}$$

and the effective damping $\beta_{eff,\ circle}^{i}$ for each cycle of loading (Fig. 2) of base-isolator *i* using:

$$\beta_{eff,\ circle}^{i} = \frac{2}{\pi}\left[\frac{E_{loop}^{i}}{k_{eff}^{i}\left(|\Delta_{max}^{+}|^{i} + |\Delta_{max}^{-}|^{i}\right)^{2}}\right]$$

The maximum effective stiffness $k_{eff,\ max}^{i}$ and minimum effective stiffness $k_{eff,\ min}^{i}$ of base isolator *i* shall be the largest and smallest k_{eff}^{i} values, respectively, estimated as given above. And, the effective damping β_{eff}^{i} of each base isolator *i* shall be the smallest of the three damping values $\beta_{eff,\ circle}^{i}$ obtained from the three cycles of testing of the base isolator *i*.

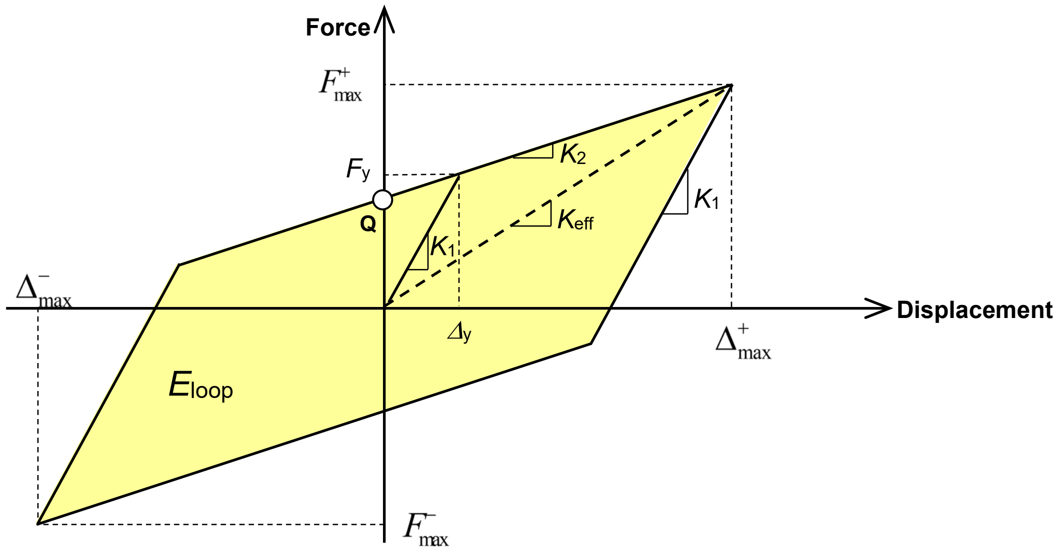


FIG. 2 FORCE-DISPLACEMENT HYSTERETIC CHARACTERISTIC OF A BASE ISOLATOR REPRESENTED BY A BILINEAR IDEALISATION

7.3 Test Specimen Adequacy

The performance obtained from a prototype test shall be considered as adequate, if the following conditions are satisfied:

a) The typical force-displacement curves obtained from all tests (conducted as per **7.1**) have a positive incremental force-carrying capacity within each cycle;
b) For each increment of test displacement specified in **7.1.1**(ii), and for each vertical load case specified in **7.1.1**, the difference is ±15 percent or lesser, between the effective stiffness at each of the three cycles of test and the average value of effective stiffness for each test specimen;
c) For each increment of test displacement specified in **7.1.1**(ii), and for each vertical load case specified in **7.1.1**, the difference is ±15 percent or lesser, between the effective stiffness of the two test specimens of a common type and size of the isolator over the required three cycles of test; and
d) All specimens of vertical load carrying elements of the base isolation system remain stable at the total design displacement under the static load prescribed in the **7.1.1**.

7.4 Production Testing for Quality Control

Production quasi-static cyclic tests shall be conducted on all base isolators supplied for a project. The test shall be performed under the combined action of compression load equal to dead load plus one-half of the effect due to live load and shear force corresponding to two-thirds of the lateral design displacement of the base isolator for at least three cycles. The tests shall be conducted to:

a) Verify the as-built properties of the isolation system, and
b) Verify and monitor the quality and consistency of the manufacturing process.

The mean of the measured properties should not vary more than 15 percent from the nominal design properties.

7.5 Design Properties of Isolation System

The prototype cyclic test shall be carried under constant compression, and the cyclic shear and the hysteresis loop obtained from the test shall be used to characterize the stiffness and damping of the base isolator. The base isolation system shall have the design properties given in sub-sections below.

7.5.1 *Maximum and Minimum Effective Stiffness of the Base Isolation System*

At the design displacement Δ_{SD}, the maximum effective stiffness $K_{eff,\ max}$ and minimum effective stiffness $K_{eff,\ min}$ of the base isolation system shall be estimated using data from the cyclic tests performed as per **7.1**, and calculated by:

$$K_{eff,max} = \frac{\sum_{i=1}^{N_{BI}} |F_i^{\ +}|_{max} + \sum_{j=1}^{N_{BI}} \left|F_j^-\right|_{max}}{2\Delta_{SD}} \text{ and}$$

$$K_{eff,min} = \frac{\sum_{i=1}^{N_{BI}} |F_i^{\ +}|_{min} + \sum_{j=1}^{N_{BI}} \left|F_j^-\right|_{min}}{2\Delta_{SD}}$$

where,

$\sum_{i=1}^{N_{BI}} |F_i^{\ +}|_{max} =$ Sum of absolute values of maximum positive forces of all individual base Isolators at a positive displacement Δ_{SD}. For a given base isolator, the maximum positive force at a positive displacement Δ_{SD} shall be determined by examining each of the maximum positive forces that occurred during each cycle of the prototype test sequence associated with displacement Δ_{SD} and selecting the maximum positive value at positive displacement Δ_{SD};

$\sum_{i=1}^{N_{BI}} |F_i^{\ +}|_{min} =$ Sum of absolute values of minimum positive forces of all individual base isolators at a positive displacement Δ_{SD}. For a given base isolator, the minimum positive force at a positive displacement Δ_{SD} shall be determined by examining each of the minimum positive forces that occurred during each cycle of the prototype test sequence associated with displacement Δ_{SD} and selecting the minimum positive value at positive displacement Δ_{SD};

$\sum_{j=1}^{N_{BI}} \left|F_j^-\right|_{max} =$ Sum of absolute values of maximum negative forces of all individual base isolators at a positive displacement Δ_{SD}. For a given base isolator, the maximum negative force at a positive displacement Δ_{SD} shall be determined by examining each of the maximum negative forces that occurred during each cycle of the prototype test sequence associated with displacement Δ_{SD} and selecting the maximum negative value at positive displacement Δ_{SD}; and

$\sum_{j=1}^{N_{BI}} |F_j^-|_{min} =$ Sum of absolute values of minimum negative forces of all individual base isolators at a positive displacement Δ_{SD}. For a given base isolator, the minimum negative force at a positive displacement Δ_{SD} shall be determined by examining each of the minimum negative forces that occurred during each cycle of the prototype test sequence associated with displacement Δ_{SD} and selecting the minimum negative value at positive displacement Δ_{SD}.

7.5.2 *Effective Damping*

At the design displacement, the effective damping β_{eff} of the *base isolation system* shall be based on the cyclic tests specified in **7.1** and estimated by:

$$\beta_{eff} = \frac{\sum_{i=1}^{N_{BI}} E_D^i}{2\pi K_{eff,max} \Delta_{SD}^2}$$

The energy dissipated E_D^i in base isolator *i* shall be estimated at test displacements Δ_{max}^- and Δ_{max}^+, which are equal in magnitude to the design displacement Δ_{SD} of the base isolator.

8 INSPECTION AND MAINTENANCE OF BASE-ISOLATORS

Two additional test isolators of each type and size shall be kept at the site of the base isolated building subjected to the same environmental condition as the isolator units of the building. These shall be tested periodically to check the impact of aging and deterioration on the mechanical properties as per **7.1**. The first test shall be performed after 15 years of the installation, and then every 3 years thereafter. Should the building experience an earthquake, whose intensity is comparable to that of the design level earthquake, the said test shall be performed immediately after such an event.

If the test indicates that the force values at any displacement in the force-displacement curves of the test isolators differ by more than ± 15 percent of the values considered in the original design of the base isolated building, the earthquake safety of the building shall be re-certified considering the average force-displacement curves as established by the tests conducted on the two additional test isolators of each type and size kept at the site of the base isolated building.

ANNEX A
(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
456 : 2000	Plain and reinforced concrete — Code of practice (*fourth revision*)
800 : 2007	General construction in steel — Code of practice (*third revision*)
875	Code of practice for design loads (other than earthquake) for buildings and structures:
(Part 1) : 1987	Dead loads — Unit weights of building material and stored materials (*second revision*)
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 2015	Wind loads (*third revision*)
IS 1893	Criteria for earthquake resistant design of structures
(Part 1) : 2025	General provisions
(Part 5) : 2025	Buildings
IS 13920 (Part 5) : 2025	Earthquake resistant design and detailing of structures Part 5 Buildings
IS 18168 : 2023	Earthquake Resistant Design and Detailing of Steel Buildings — Code of Practice

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