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)

मानक भवन, 9, बहादुर शाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002
Phones: 23230131 / 2323375 / 23239402
Website: www.bis.gov.in, www.manakonline.in

व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 39/टी- 34 **15 अक्टूबर 2024**

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(26742)WC	**संरचनाओं का भूकंप सुरक्षा मूल्यांकन और पुनःसंयोजन** **भाग 2 भवन** (IS 13935 का दूसरा 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: 30 नवम्बर 2024

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।

यदि कोई सम्मति प्राप्त नहीं होती है अथवा सम्मति में केवल भाषा संबंधी त्रुटि हुई तो उपरोक्त प्रालेख को यथावत अंतिम रूप दे दिया जाएगा। यदि सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रालेख को अंतिम रूप दे दिया जाएगा।

यह प्रालेख भारतीय मानक ब्यूरो की वेबसाइट **www.bis.gov.in** पर भी उपलब्ध हैं।

धन्यवाद।

भवदीय
ह-/
द्वैपायन भद्र
वैज्ञानिक ई एवं प्रमुख
सिविल अभियांत्रिकी विभाग

संलग्न: उपरलिखित

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)

मानक भवन, 9, बहादुर शाह ज़फर मार्ग, नई दिल्ली – 110002
Manak Bhawan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002
Phones: 23230131 / 2323375 / 23239402
Website: www.bis.gov.in, www.manakonline.in

WIDE CIRCULATION DRAFT

Our Reference: CED 39/T- 34 **15 October 2024**

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(26742)WC	Draft Indian Standard Earthquake Safety Assessment and Retrofitting of Structures **Part 2 Buildings** (Second Revision of IS 13935) 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: 30 November 2024

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(26742)WC

BIS Letter Ref: CED 39/T- 34

Title: Draft Indian Standard Earthquake Safety Assessment and Retrofitting of Structures Part 2 Buildings (Second Revision of IS 13935) ICS No. 91.120.25

Last date of comments: 30 November 2024

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*

BUREAU OF INDIAN STANDARDS

DRAFT STANDARD FOR COMMENTS ONLY

(Not to be reproduced without the permission of BIS or used as an Indian Standard)

Draft Indian Standard

Earthquake Safety Assessment and Retrofitting of Structures
Part 2 Buildings

(*Second Revision* of IS 13935)

Earthquake Engineering	**Last Date for Comments:**
Sectional Committee, CED 39	**30 November 2024**

FOREWORD

[*Formal clause will be added later*]

The stock of housing in India alone is over 32 Crores, and the stock of the other structures is of a comparable number. A significant share of this stock is located in landmass that is likely to sustain moderate to severe earthquake ground shaking. Much of this existing stock of structures in India is unregulated construction, owing to absence of necessary techno-legal process to examine the structural safety of the built environment at the municipal offices across the country. Past earthquakes in India show that large losses of life is attributed primarily due to the collapse of structures. To prevent large losses of lives in earthquakes in future, it is essential to assess and retrofit structures before the impending earthquakes.

IS 13935 was first published in 1993 with the title 'Seismic evaluation, repair and strengthening of masonry buildings — Guidelines', and revised in 2009. In 2022, to keep abreast with rapid developments and extensive research carried out worldwide in earthquake engineering, the Committee decided to present the provisions for different types of structures in 11 separate parts, namely:

Part 1 General Provisions
Part 3 Liquid Retaining Tanks
Part 4 Bridges and Retaining Walls
Part 5 Industrial Structures
Part 6 Base Isolated Buildings
Part 7 Pipelines
Part 8 Dams and Embankments
Part 9 Coastal Structures
Part 10 Steel Towers
Part 11 Tunnels

These 11 separate parts are created in each of the following standards with revised titles as:

a) IS 1893 Design earthquake hazard and criteria for earthquake resistant design of structures;
b) IS 13920 Earthquake resistant design & detailing of structures; and
c) IS 13935 Earthquake safety assessment and retrofitting of structures.

In this second revision, the following changes have been made:

a) Earthquake hazard levels are specified for design of retrofit, depending on the age of the structure;
b) Levels of assessment of a structure are specified;
c) Load combinations to be used are specified when performing structural analysis for assessment or retrofit;
d) Virtues are identified, which need to be improved by global and local retrofit of the structure; and
e) Requirements are specified related to configuration, stiffness, strength and deformability of the structure to qualify retrofit options.

In India, on one side, the stock of structures is large, typologies are many, and variations within each typology are significant. And, on the other side, the professional services are of varying competence. Hence, there are many nuances in assessment of structures to resist earthquake. In the development of this standard, this was recognized, and the evaluation of structures to examine their sufficiency to resist the earthquake shaking effects is recommended to be performed at five levels, namely:

a) Level 0 Basic prioritization,
b) Level 1 Field assessment,
c) Level 2 Preliminary quantitative (hand-calculation) evaluation,
d) Level 3 Basic quantitative (code compliance) evaluation, and
e) Level 4 Detailed quantitative (nonlinear) evaluation.

The assessment at Levels 0 and 1 are qualitative assessment, while the evaluations at Levels 2 to 4 are quantitative evaluations. This telescopic method provides a way of prioritizing the structures for earthquake assessment and retrofit. The standard is expected to be used by competent engineers, who have sufficient experience of having designed sufficient number of structures and have a reasonably good understanding of loads, structural behavior and structural design to sustain and resist the effects of loading.

A general guidance on the cost of retrofitting of buildings (as a percentage of the reconstruction project cost, excluding the cost of land) is:

a) In office and residential buildings, if the cost of retrofit is:

    1) Less than 30 percent, it is best to implement the retrofit scheme,
    2) More than 50 percent, it is best to reconstruct, and
    3) Between 30 percent to 50 percent, more considerations are needed on downtime and funding to decide either way (retrofit or reconstruct),

b) In critical & lifeline buildings, if the cost of retrofit is:

1) Less than 50 percent, it is best to implement the retrofit scheme,
2) More than 70 percent, it is best to reconstruct, and
3) Between 50 percent to 70 percent, more considerations are needed on downtime and funding to decide either way (retrofit or reconstruct), and

c) In heritage buildings, the cost of retrofit is viewed from many other considerations that are beyond the scope of this standard. Hence, the decision to retrofit or not is more involved.

This guidance should be considered along with the broad principle of prioritization for undertaking the retrofitting work in a phased manner as per CED 39 (26741) (Part 1), that is starting from: (a) the buildings in earthquake zone VI and eventually buildings in earthquake zone II, and (b) the special and critical buildings and eventually important and normal buildings. Owners of privately owned buildings also shall adopt this guidance, even though the costs are to be borne by them.

In the preparation of this standard, effort has been made to coordinate with standards and practices prevailing in different countries in addition to relating it to the practices in the field in this country. Assistance has particularly been derived from the following publications:

a) ISO 16711 (2021) Requirements for Seismic assessment and retrofit of concrete structures, 2nd Edition, The International Standards Organisation
b) Brzev,S.N., and Begaliev,U., (2018), Practical Seismic Design and Construction Manual for Retrofitting Schools in the Kyrgyz Republic, The World Bank.

The units used with the items covered by the symbols shall be consistent throughout this standard, unless specifically noted otherwise.

This standard contributes to the United Nations Sustainable Development Goal 9: ‘Industry, innovation and infrastructure’, particularly its target to develop quality, reliable, sustainable and resilient infrastructure, and also promote inclusive and sustainable industrialization.

The composition of the Committee responsible for the formulation of this standard is given in Annex B.

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.

BUREAU OF INDIAN STANDARDS

DRAFT STANDARD FOR COMMENTS ONLY

(Not to be reproduced without the permission of BIS or used as an Indian Standard)

Draft Indian Standard

Earthquake Safety Assessment and Retrofitting of Structures
Part 2 Buildings

(*Second Revision* of IS 13935)

Earthquake Engineering	**Last Date for Comments:**
Sectional Committee, CED 39	**30 November 2024**

1 SCOPE

1.1 The provisions of this standard are applicable to:

a) Existing masonry and concrete buildings for assessing their adequacy to resist design earthquake shaking; and retrofitting them to make them earthquake resistant. and
b) New masonry and concrete buildings for evaluating their earthquake performance under design earthquake shaking.

1.2 The provisions of this standard are not applicable to the buildings built with:

a) Precast concrete components,
b) Prestressed members, and
c) Pre-engineered members.

2 REFERENCES

The standards given in Annex A contain provisions which, through reference in this text, 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 given in Annex A.

3 TERMINOLOGY

For the purpose of this standard, definitions given below shall apply to all structures, in general. Reference may be made to the following standards for definitions of terms pertaining to:

a) Effects due to earthquakes: IS 1893 and IS 13920; and
b) Loads other than due to earthquakes: IS 875 (Parts 1 to 5).

3.1 Acceptance Criteria — Limiting values of structure characteristics (such as lateral

drift, lateral strength and lateral inelastic deformation) used to determine the acceptability of a component.

3.2 Action — Internal stress resultants (axial load, shear force, bending moment and torsional moment) and deformations (strains, deflections and rotations) developed in a member due to externally applied load or displacement on the structure.

3.3 Diaphragm — A horizontal plate-like element in a structure, which participates in transferring the earthquake-induced lateral inertial forces, between the vertical and inclined components of the structure resisting the said lateral inertial forces.

3.3.1 *Flexible Diaphragm* — An element that deforms in its own horizontal plane, such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the element is more than 1.5 times the average displacement of the entire element.

3.3.2 *Rigid Diaphragm* — An element that deforms in its own horizontal plane, such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the element is less than 1.5 times the average displacement of the entire element.

3.4 Infill — A panel of masonry placed within a steel or concrete frame. Panels separated from the surrounding frame by a gap are termed isolated infills. A panel in tight contact with a frame around its full perimeter is termed a shear infill.

3.5 Jacketing — A method by which an existing concrete column or concrete beam is covered along the perimeter with steel plates, reinforced concrete or fiber reinforced plastic sheets.

3.6 Load-Bearing Wall — A wall designed to carry applied vertical load in addition to its own weight, together with any lateral load.

3.7 Pounding — Two adjacent buildings impact during earthquake excitation, because they are too close together.

3.8 Short Column — A vertical member of a building, whose behaviour is controlled largely by axial and shearing deformations and not by bending deformations.

3.9 Strengthening Method — A procedure for the reduction of earthquake vulnerability of the building.

4 SYMBOLS

For the purpose of this standard, symbols and notations given below shall apply to all structures, in general. For symbols and notations pertaining to:

a) Earthquake effects, reference may be made to IS 1893 (Part 1 to Part 11) and IS 13920 (Part 1 to Part 11); and
b) Loads other than due to earthquakes, reference may be made to IS 875 (Part 1 to Part 5).

Symbol	*Description*

SECTION 1 GENERAL PRINCIPLES FOR ALL BUILDINGS

5 ASSESSMENT OF EARTHQUAKE SAFETY OF ALL BUILDINGS

5.1 The need for assessing and/or retrofitting buildings may arise from any of the following reasons:

a) Deterioration of the materials over time,
b) Change of use proposed by the owner,
c) Changes in design codes, and
d) Requirement of statutory bodies.

The provisions specified hereunder are applicable to buildings not damaged by earthquake shaking and not to buildings damaged by earthquake shaking. The assessment of existing structures shall be performed as per the philosophies, principles and requirements specified hereunder.

5.2 General Provisions

a) Buildings shall be assessed as per the 5-level assessment procedure specified in CED 39 (26741) (Part 1).
b) Single- or two-storey buildings (not housing essential services required for post-earthquake disaster management activities) of total plinth area less than 30 m^2 are exempted from level 3 simplified quantitative assessment or level 4 detailed quantitative assessment even when level 2 detailed qualitative assessment indicates deficiencies and where earthquake retrofitting is carried out to remedy those deficiencies.

5.3 Building Information

The data mentioned hereunder shall be ascertained regarding the building to be assessed.

5.3.1 *Data Available*

The following information shall be collected:

a) Basic information, including details of inspection team, building identity, structural system, structural components and occupancy.
b) In-situ soil investigations, by fresh investigations, if not available already with the owner,
c) Original design basis reports (*DBRs*) and structural design calculations,
d) Architectural and structural drawings,
e) Current member condition, by fresh investigations conducted within the last 1 month of the assessment, and
f) In-situ material properties, by fresh investigations conducted within the last 1 year of the assessment.

5.3.2 *Data Unavailable*

Any information that is unavailable (for whatsoever reason) in **5.6**, the same shall be recorded explicitly for suitable decision making when dealing with requirements of **5.6.1** and **5.6.2**.

5.4 Method of Assessment

The methods of assessment admissible are specified hereunder.

a) Working Stress Method shall be employed for assessing masonry buildings, subject to following modifications:

   1) The factors of safety on material strengths shall be taken as specified in IS 1905, but to be applied on the mean values of strengths obtained from fresh investigations, and not on the characteristic values of the original material at the time of construction, and
   2) The design loads shall be taken as specified in **7.5** of CED 39 (22343); and

b) Limit State Method shall be employed for assessing reinforced concrete buildings, subject to the following modifications:

   1) Partial safety factors on material strengths shall be taken as specified in IS 456, but applied on the mean values of strengths obtained from fresh investigations, and not on the characteristic values of the original material at the time of construction; and
   2) The design loads shall be taken as specified in **7.5** of CED 39 (22343).

5.5 Assessment of Earthquake Lateral Force Demand

For Level 2, 3 and 4 assessments of buildings, the earthquake demand shall be estimated as per CED 39 (22343) and CED 39 (22345) as specified hereunder.

5.5.1 *Importance Factor (I)*

The importance factor I shall be taken as 1.0.

5.5.2 *Elastic Force Reduction Factor (R)*

The elastic force reduction factor R for buildings with different structural systems shall be taken as per Table 5 of CED 39 (22345) and others shall be as per Table 1.

5.5.3 *Assessment Acceleration Coefficient*

The assessment level earthquake lateral and vertical accelerations shall be estimated as per procedure specified in **5.2.3.1** of CED 39 (22345), with the return period of earthquake hazard taken as per Table 2.

5.5.4 *Assessment Level Earthquake Lateral and Vertical Forces*

The assessment level earthquake lateral and vertical forces shall be estimated by the same procedure as the design level earthquake lateral force specified in **5.2.3** of CED 39 (22345), but using:

a) Importance factor as specified in **5.5.1**,
b) Elastic force reduction factor R as specified in **5.5.2**, and
c) Design lateral and vertical accelerations as specified in **5.5.3**.

5.5.5 *Load Combinations*

The earthquake loads estimated in **5.5.4** shall be combined with the other loads as per load combinations specified in **5.3.2** of CED 39 (26741) (Part 1) with the return period of earthquake hazard taken as per Table 2.

Table 1 Elastic Force Reduction Factor *R* for Buildings with Structural Systems not provided in CED 39 (22345)
(*Clause* 5.5.2)

Sl No.	**Structural System**	***R***
(1)	(2)	(3)
i)	*Load-Bearing Masonry Buildings with*	
	Unreinforced masonry walls (designed and detailed as per IS 1905) and Special RC Structural Walls without boundary elements (SSWs–RC-NBE) (designed and detailed as per IS 13920)	1.5
	Unreinforced masonry walls (designed and detailed as per IS 1905) and Special RC Structural Walls with boundary elements (SSWs–RC-BE) (single SW, or coupled SW) (designed and detailed as per IS 13920)	1.5
ii)	*Reinforced Concrete Buildings with Moment Frames*	
	Ordinary Moment Resisting Frames (OMRFs–RC) (designed and detailed as per IS 456) and SSWs–RC-NBE (designed and detailed as per IS 13920)	3.0
	OMRFs–RC (designed and detailed as per IS 456) and SSWs–RC-BE (single SW, or coupled SW) (designed and detailed as per IS 13920)	3.0
	OMRF-RC with Flat slab (designed and detailed as per IS 456) and SSWs–RC-NBE (designed and detailed as per IS 13920)	3.0
	OMRF-RC with Flat slab (designed and detailed as per IS 456) and SSWs–RC-BE (single SW, or coupled SW) (designed and detailed as per IS 13920)	3.0

Table 2 Return Period T_{RP} (years) to be used for the Earthquake Safety Assessment and Retrofit
(*Clause* 5.5.3 *and* 5.5.5)

Building's Sub-Category	Return Period T_{RP} (years)	
	Masonry Buildings	Concrete Buildings
(1)	(2)	(3)
1	175	475
2	275	975
3	475	2 475
4	975	4 975

5.5.6 *Structural Analysis*

For Level 2, 3 and 4 assessments of buildings, the stress-resultant demands on members shall be estimated as specified hereunder.

5.5.6.1 *Level 2 assessment*

In Level 2 assessment, only storey shear forces are required. Hence, this assessment shall be based on estimation of lateral shear forces considering only equilibrium equations.

5.5.6.1 *Level 3 and Level 4 assessments*

In Level 3 and 4 assessments, member stress-resultants and nodal deformations are required. Hence, these assessments shall be based on formal structural analysis considering all three sets of governing equations, namely equilibrium equations, compatibility conditions and constitutive laws.

a) *Analytical Model*

All concrete as well as masonry elements shall be included in the model, which shall be prepared as per **5.3.1** of CED 39 (26741) (Part 1). The effective section properties of members shall be taken as per Table 2 of CED 39 (22345) in the linear structural analysis of buildings.

b) *Method of Analysis*

The analytical model of the building shall be prepared as per **5.3.1** of CED 39 (26741) (Part 1).

5.6 Assessment of Earthquake Capacity

The provisions given hereunder shall be applicable when estimating assessment of earthquake capacity of the structure.

5.6.1 *Material Strength*

The probable current strengths of materials of existing buildings shall be estimated by any of these two methods:

a) Using on-site non-destructive and laboratory tests on a series of samples taken from the building. Field tests are indicative tests and shall be supplemented with appropriate laboratory studies for guiding decision making on accurate quantitative results; and
b) Using probable original material strengths given in the original building documents (if available) multiplied with default values of Knowledge Factor K given in Table 3 to account for uncertainties in the reliability of the available information and of the present condition of the members.

Table 3 Knowledge Factor *K on* Original Strengths of Materials
(*Clause* 5.6.1)

Sl No.	**Description of Building**	**Knowledge Factor** (*K*)
(1)	(2)	(3)
i)	Original construction documents available, including post-construction activities, such as modification to structure, and testing of materials undertaken of existing structure	1.0
ii)	Documentation as in Sl No.(i) above, and no testing of materials	0.9
iii)	Documentation as in Sl No.(i) above, no testing of materials, and minor deterioration of original condition	0.8
iv)	Incomplete but useable original construction documents, and no testing of materials	0.7
v)	Incomplete or no documents available, but extensive testing and inspection done to establish current strengths of load resisting members	0.7
vi)	Documentation as in Sl No.(iv) above, limited inspection, and verification of structural members, or materials test results with large variation	0.6
vii)	Little knowledge of details of a component	0.5

5.6.2 *Member Strength*

The probable current design capacity of members of existing buildings shall be estimated using the procedures given in sections 1 and 2 of IS 13920 (Parts 1 and 2) for masonry buildings and sections 1 and 3 of IS 13920 (Parts 1 and 2) for concrete buildings. The materials strength shall be obtained as per **5.6.1**.

The member strengths obtained above shall be multiplied by the Member Condition Factor C specified in Table 4 for masonry buildings and Table 5 for concrete buildings.

Table 4 Member Condition Factor C for Members of Masonry Buildings
(*Clause* 5.6.2)

Sl No.	**Deficiency in Members**	**Member Condition Factor C**
(1)	(2)	(3)
i)	**All of the following:** a) *Masonry units* No deterioration is visible of masonry units. b) *Masonry joints* Mortar cannot be easily scraped away from the joints by hand or with a metal tool. And, mortar has not eroded in any area of the masonry wall. c) *Cracks in walls* No crack is visible of masonry walls.	1.0
ii)	**All of the following:** a) *Masonry units* No deterioration is visible of masonry units. b) *Masonry joints* Mortar cannot be easily scraped away from the joints by hand or with a metal tool. And, mortar has not eroded in any area of the masonry wall. c) *Cracks in walls* Cracks visible in masonry walls. Cracks do not pass through walls and are not more than 3 mm thick on the outer face. There is no out-of-plane offsets in the bed joint more than 3 mm.	0.8
iii)	**Any of the following:** a) *Masonry units* Deterioration is visible of masonry units. b) *Masonry joints* Mortar can be easily scraped away from the joints by hand or with a metal tool. And, mortar has eroded in some area of the masonry wall. c) *Cracks in walls* Cracks visible in masonry walls. Cracks pass through walls and are more than 3 mm thick on the outer face. There is out-of-plane offsets in the bed joint more than 3 mm.	0.5

Table 5 Member Condition Factor C for Members of Concrete Buildings
(*Clause* 5.6.2)

Sl No.	**Deficiency in Members**	**Member Condition Factor C**
(1)	(2)	(3)
i)	**All of the following:** a) *Concrete* No deterioration is visible in concrete No crack is visible in the member b) *Longitudinal reinforcement* No longitudinal crack is visible in concrete c) *Transverse reinforcement* Transverse ties are not exposed d) *Member sizes* (EI/L) of columns is more than that of the beams	1.0
ii)	**All of the following:** a) Concrete No deterioration is visible in concrete No shear crack but flexural cracks are visible in the member b) *Longitudinal reinforcement* No dilation is visible of concrete No longitudinal crack is visible in concrete c) *Transverse reinforcement* Transverse ties are not exposed. d) *Member Sizes* (EI/L) of columns is more than that of the beams.	0.9
iii)	**All of the following:** a) *Concrete* Deterioration is visible in concrete No shear cracking but flexural cracks are visible in the member b) *Longitudinal reinforcement* Longitudinal cracks are visible in concrete c) *Transverse reinforcement* Transverse ties are not exposed d) *Member sizes* (EI/L) of columns is more than that of the beams	0.7
iv)	**Any of the following:** a) *Concrete* Deterioration is visible in concrete Shear cracking is visible in the member b) *Longitudinal reinforcement* Longitudinal cracks are visible in concrete Longitudinal bars are exposed by spalling of concrete	0.5

Longitudinal bars are corroded

c) *Transverse reinforcement*

Dilation is visible of concrete

Transverse bars are exposed by spalling of concrete

Transverse bars are corroded

d) *Member sizes*

(EI/L) of columns is less than that of the beams

5.7 Acceptance Criteria

A building is said to be acceptable, if:

a) Requirements given in **5.7.1** are satisfied by all members; or
b) Requirements given in **5.7.1** are satisfied by all critical members (that is members of lateral force resisting system) and by most of the remaining members, and it is established that the failure of the remaining members that do not meet the requirements given in **5.7.1**, shall not lead to loss of stability of the building or initiate its progressive collapse. This shall be established by a nonlinear analysis (such as Pushover Analysis) carried out up to the collapse load.

Else, the building shall be declared to undergo retrofit, and the deficiencies shall be identified at the structure and member levels.

A retrofitted building also shall meet the above acceptance criteria.

5.7.1 *Special Requirements*

a) *Strength*

In all members, the demand-capacity strength ratios of all stress-resultants (as specified in the respective standards, namely IS 1905 for masonry members, IS 456 for concrete members and IS 800 for steel members) shall be less than 1.

b) *Stiffness*

The lateral inter-storey drifts shall be less than the values permissible in **5.2.2.2** of CED 39 (22345), under the action of earthquake load combinations specified in **7.5** of CED 39 (22343) but with the earthquake load taken as per **5.5**.

5.8 Identification of Deficiencies

The checks on the compliance of the various provisions shall be used to identify the following deficiencies in level 2, 3 and 4 assessments:

a) at the overall structure level, and
b) at the member level.

6 EARTHQUAKE RETROFIT OF ALL BUILDINGS

This clause outlines earthquake retrofit options and strategies at a general level, and describes a methodology for the design of the retrofit measures as modifications to correct/reduce earthquake deficiency identified during the evaluation specified in **5.7**.

A retrofit measure adopted shall enhance the required characteristic of the existing building in which it is deficient. This standard addresses the following characteristics of the building:

a) Structural integrity,
b) Structural configuration,
c) Overall lateral stiffness,
d) Overall lateral strength, and
e) Overall lateral deformability.

It shall be demonstrated quantitatively that the retrofit measure adopted does enhance the characteristic(s) required to be met with by the building, as per Table 4 and Table 5.

6.1 Strategies of Retrofit

To overcome the deficiencies identified in **5.8**, two options shall be explored, namely:

a) Reduce the earthquake demand on the building, or/and
b) Enhance capacities of the structure and members.

6.1.1 *Reduce Earthquake Demand*

The following are options for reducing earthquake demand on members:

a) Modify the functional use of the buildings, towards reducing the mass of the building,
b) Introduce new stiff and strong structural elements in the building, towards diverting most of the earthquake lateral force to the new elements added (such as structural walls and braces), and relieve most of the existing members from the earthquake deformation demand and stress-resultants, and
c) Introduce new:

    1) Supplemental Energy Dissipation Devices in the different storeys of existing buildings, towards increasing damping in the building and reducing its overall reduction in lateral displacement. This measure is most effective in buildings that are relatively flexible and are designed to sustain inelastic deformation. and
    2) Base Isolation Devices at the base of the existing building, towards reducing the earthquake demands on the elements of the building. This measure is most effective in relatively stiff buildings with low heights and large mass compared to light and flexible structures.

6.1.2 *Increase Earthquake Capacity*

The options for enhancing earthquake capacity of members are provided in **6.2**.

6.2 Levels of Retrofit

Depending on the structure or member deficiency identified in **5.8**, retrofit measures may be considered at any or all of the system, member and material levels.

6.2.1 *System Level*

In buildings where more than a few critical members and components do not have adequate strength and ductility, an effective way is to strengthen the whole structure so that the overall displacement demands shall be reduced. The force demands may be enhanced in some other elements, which, in turn, may require further strengthening; this shall be examined suitably. Introducing structural walls and braces are effective ways of adding stiffness and strength.

6.2.1.1 *Improve structural integrity*

Brittle and weak buildings have poor integrity, that is members have insufficient stiffness and strength to resist the overall deformation and force demands induced during earthquakes. Appropriate measure shall be identified to enhance the overall integrity of the building, towards precluding local failure of members that cause partial or full collapse of buildings.

6.2.1.2 *Reduce structural irregularity*

Irregularities related to distribution of strength, stiffness and mass result in poor earthquake performance. Often, these irregularities exist because of discontinuity of structural members. Simple removal of such discontinuities may reduce earthquake demand on other structural components to acceptable levels.

a) *Mass*

   Mass irregularity can be reduced by changing functional use of the building, and therefore reducing the mass at locations where it is considered to be higher.

b) *Stiffness*

   Unsymmetrical strength in the plan of buildings (causing twisting in buildings during *elastic* response of buildings) can be corrected by introducing new stiff structural elements at locations where the lateral stiffness is considered to be lesser. The best suited location shall be determined by examining the elastic modes of vibrations of buildings.

   An effective measure to correct vertical irregularities such as soft and/or weak storey is the addition of structural walls and braces within the deficient storey. Structural walls and braces may be used effectively to balance stiffness and mass distribution within a storey to reduce torsional irregularity. Structural walls

and braces shall be placed such that they form an integral part of load path for flow of lateral loads.

c) *Strength*

Unsymmetrical strength in the plan of buildings (causing twisting in buildings during inelastic response of buildings) can be corrected by introducing new stiff structural elements at locations where the lateral stiffness is considered to be lesser. The best suited location shall be determined by examining the inelastic response of buildings.

d) *Twisting*

Structural walls and braces shall be constructed along each orthogonal plan direction on opposite side of shear center, and as far away from the shear center as possible to offer torsional resistance to the entire structure. The center of lateral resistance of the complete structure at a floor level after adding the structural walls and braces shall be such that its eccentricity with respect to center of mass is reduced to a minimum.

e) *Seismic joints*

Movement gaps shall be provided between two portions of a building with irregular plan geometry to separate the building into a number of regular independent buildings. But, care shall be taken to provide sufficient wide gaps between the separated parts of the building to avoid them from pounding on each other during earthquake shaking.

6.2.1.3 *Increase soil strength*

When required, ground improvement measures shall be employed to improve the soil. Vibro-compaction or soil replacement may be adopted to consolidate the underlying soil and thereby strengthen and stiffen it.

6.2.2 *Member Level*

This level of retrofit shall be undertaken only after it is established that the building meets the system deficiencies. Further:

a) Buildings with a sufficient level of strength and stiffness at the structure level may have some members (or components), which lack adequate strength, stiffness or ductility. If such deficient members are small in number, an economical and appropriate strategy is to modify these deficient members alone while retaining the existing lateral-force resisting system.
b) Member level modification shall be undertaken to improve strength, stiffness and/or ductility of deficient members and their connections. For instance, modifications may be made to meet the desired strength demand-capacity ratio.
c) Member level strengthening measures that enhance ductility of the member without significantly increasing its strength/stiffness are useful when analysis indicates that a few members of the lateral-load resisting system are deficient.

For instance, modifications may be made to meet the desired plastic rotation capacity of specific members.

6.2.3 *Material Level*

Brittle materials (like masonry and concrete) have low material ductility, and hence cannot resist plastic deformations; this limits the overall deformability of buildings. The retrofit measures can increase tensile and compressive strengths of materials, which together enhance ultimate compressive strain of the material, and thereby the overall strain ductility capacity of the material.

One action that addresses both of these needs is confinement of the material. Hence, methods of confinement have been devised to enhance the material strain capacities.

6.3 Strategy

The following additional strategies shall be adopted:

a) Global safety of the building is assured first, before examining the local effects; and
b) Local failures shall be precluded by examining that:
   1) Provisions of CED 39 (25408) are complied with; and
   2) Architectural Elements and Utilities are safe as per the demands estimated by CED 39 (22343) and resistance estimated by CED 39 (22345).

6.4 Choice of Retrofit Scheme

The potential scheme of retrofit are filtered through the following sequence:

6.4.1 *Available Options*

The potential alternatives of retrofit schemes that require the least modifications to the existing structure are considered as available options of retrofit.

6.4.2 *Feasible Alternatives*

Of the short-listed available options of retrofit, those which can be implemented at site without excessive disruption to the occupants of the structure are considered as *feasible alternatives* of retrofit.

6.4.2 *Active Options*

Of the short-listed feasible options of retrofit, those whose costs are most reasonable are the active options.

SECTION 2 ADDITIONAL PRINCIPLES FOR MASONRY BUILDINGS

7 ASSESSMENT

The method of assessment specified hereunder is applicable to the masonry buildings made of:

a) Brick masonry units only,
b) Stone masonry units only,
c) Cement block masonry units only, and
d) Hybrid brick-stone masonry.

7.1 Levels of Assessment

Buildings shall be assessed as per the telescopic method specified in **5.1** and Fig. 1 of CED 39 (26741) (Part 1). The use of Level 0 Assessment for movement to the higher levels of assessment also shall be guided by the said provision.

The basic information of a masonry building shall be recorded as per Table 6.

7.1.1 *Level 0: Basic Prioritization*

The basic information of a masonry building shall be recorded as per Table 6. The impact of the basic prioritization as low, medium and high shall be taken as per Table 1 of CED 39 (26741) (Part 1).

7.1.2 *Level 1: Field Assessment*

The Field Assessment of a masonry building shall be performed as per:

a) Table 7 for examining life threatening factors, and
b) Table 8 for examining economic loss inducing factors.

Table 6 Basic Information of Masonry Buildings needed for Level 0 Assessment
(*Clause* 7.1 *and* 7.1.1)

TYPE	DETAILS		
(1)	(2)		
Inspection Team	**Identification**	**Date**	**Time**
	Inspector 1	**Inspector 2**	**Inspector 3**
Building Identity	**Building Name**	**Address**	**Coordinates**
			*N*_____^{o} *E*_____^{o}
Structural System	**Load-bearing Masonry with** *(Tick ONE)*	☐ *Igneous Rocks* ☐ *Sedimentary Rocks* ☐ *Slate Blocks*	☐ *Others (Please describe)* _____
Structural Components	**Floor System** *(Tick ONE)*	☐ *RC Slab* ☐ *Timber Planks & Beams*	☐ *Others (Please describe)* _____
	Roof System *(Tick ONE)*	**Material**	**Geometry**
		☐ *RC Slab*	☐ *Flat*
		☐ *Wooden Truss with Clay Tiles*	☐ *Pitched*
		☐ *Corrugated Sheets*	☐ *Hipped*
		☐ *Wood Planks*	☐ *Others (Please describe)* _____
		☐ *Steel Truss with Corrugated Sheeting Roof*	
		☐ *Others (Please describe)* _____	
	Wall Masonry Mortar *(Tick ONE)*	☐ *Cement*	☐ *Mud*
		☐ *Lime*	☐ *Others (Please describe)* _____
Occupancy *(Tick ONE)*	**Residential**	☐ *Individual House*	☐ *Apartment*
	Educational	☐ *School*	☐ *College*
		☐ *Institute or University*	

	Lifeline	☐ *Hospital*	☐ *Police Station*
		☐ *Fire Station*	☐ *Power Station*
		☐ *Water Plant*	☐ *Sewage Plant*
	Commercial	☐ *Hotel*	☐ *Shopping*
		☐ *Recreational*	
	Office	☐ *Government*	☐ *Private*
	Mixed Use	☐ *Residential-Commercial*	☐ *Residential-Industrial*
	Others	☐ *Please describe* _____	

Basic Prioritization			
			Priority
i) The structure was designed originally to resist earthquake effects, but			
a)	The structure is being modified to carry heavier loading	☐ *Yes*	Low
		☐ *No*	
b)	Standard is revised and the provisions are more stringent related to: 1) Design earthquake hazard, and/or 2) Design and detailing of structures	☐ *Yes*	Medium
		☐ *No*	
c)	Structure is being extended and/or modified	☐ *Yes*	Medium
		☐ *No*	
d)	The structure is damaged (not by an earthquake) and/or deteriorated substantially	☐ *Yes*	High
		☐ *No*	
ii) The structure was not designed originally to resist earthquake effects.		☐ *Yes*	High
		☐ *No*	
iii) “No” in all of the above			Low

Table 7 Level 1 Assessment of Masonry Buildings for Life Threatening Factors
(*Clause* 7.1.2)

Sl No.	Feature	Parameters (Tick all applicable)	Tag
(1)	(2)	(3)	(4)
i)	Siting and Ground Issues	Building has at least one of the following	
		1) Site is an old failed landslide or fissured land.	Red
		2) Site rests on hill slopes or adjacent to hill slopes, which are vulnerable to sliding during earthquakes.	Red
		3) Site rests on adjoining a damaged, tilted or uphill building.	Red
		4) Ground is a river terrace that can slide or creep.	Red
		5) Ground is vulnerable to falling debris from uphill.	Yellow
ii)	Soil and Foundation Conditions	Building has at least one of the following	
		1) Soil underneath is likely to undergo uneven settlement.	Red
		2) Soil underneath is susceptible to liquefaction.	Red
		3) Soil is weak or non-uniform soil along the long dimension in plan.	Yellow
iii)	Architecture Features and Elements	Building has at least one of the following	
		1) Outer dimensions at plinth level less than those at the top in any of the two plan directions.	Red
		2) Vertical projections and horizontal overhangs are large, heavy and unanchored.	Red
		3) Upper storeys are heavier than the lower ones.	Red
		4) Location is adjacent to damaged building.	Red
		5) Plan aspect ratio is more than 3.	Yellow
		6) Plan geometry is irregular.	Yellow
		7) Water tanks on roof are unanchored.	Yellow
		8) Room sizes and storey heights are large.	Yellow
		9) Cantilever balconies or sunshades are large or heavy.	Yellow
		10) Windows openings are more than 50% of the length of the wall.	Yellow
iv)	Structural Aspects	Building has at least one of the following	
		1) Adjoining building is too close and likely to pound with it.	Red
		2) Building is tilted or adjoins another unsafe building with no gap.	Red
		3) Staircase or stair cabin is damaged.	Red
		4) Plinth masonry is severely damaged.	Red
		5) Masonry walls are of half brick or brick on edge.	Red
		6) Masonry walls have separated at the corners.	Red
		7) No lintel band is present if roof is flat, no gable band if roof is sloped, and no eaves levels if the roof is pitched.	Red

		8) Floor-wall junction is separated with walls going out-of-plumb.	Red
		9) An open storey exists at ground or any other level with slender piers.	Red
		10) Masonry walls are thick and separated into wythes.	Red
		11) The adjoining building has settled unevenly.	Red
		12) Horizontal projections or overhangs rest on 1 brick or 1½ brick thick unreinforced masonry walls.	Red
		13) Roof has slid horizontally over the masonry walls.	Red
		14) Masonry wall is crushed at its all base or at any other level.	Red
		15) Openings in walls are large and close to corners and wall junctions.	Red
		16) Walls are unsymmetrically positioned along each plan direction.	Yellow
v)	Material & Construction Details	Building has at least one of the following	
		1) Mud mortar and units in walls are significantly deteriorated.	Yellow
		2) Mortar is not used or eroded at bed and head joints in walls.	Yellow
		3) Quality of units and mortar is poor.	Yellow
		4) Quality of construction is poor.	Yellow
vi)	All	None of the above	Green

RATING		
If GREEN flag only *with no RED or YELLOW Flag* *Perform* *Level 2 Assessment*	If YELLOW flags only *with no RED Flag* *Perform at least* *Level 3 Assessment*	If at least one RED Flag *Perform* *Level 4 Assessment*

SUGGESTED INTERVENTIONS		
Actions		
Building to be SEALED	☐ *YES*	☐ *NO*
Building to be DEMOLISHED	☐ *YES*	☐ *NO*

Table 8 Level 1 Assessment of Masonry Buildings for Economic Loss Inducing Factors
(*Clause* 7.1.2)

Sl No.	Feature	Parameters (Circle all applicable penalty points)	Penalty
(1)	(2)	(3)	(4)
i)	Siting and Ground Issues	a) Building has the following Siting Issues	
		1) The house is on sloped ground with access to house at two/three levels, that is ground middle floor and roof.	5
		2) The house is built on unstable ground that can slide or liquefy.	5
		Sub-total (Maximum Total Penalty Points is 5)	
ii)	Soil and Foundation Conditions	a) Suitability of soil	
		1) The soil is soft soil, that is,_____.	2
		2) The soil is weak soil, that is,_____.	2
		3) The water table is high, that is,_____.	1
		4) The soil is moist in most months of the year, that is, _____.	2
	Foundation	b) Suitability of foundation	
		1) The strip foundation is of masonry and resting on a non-uniform base.	2
		2) The plinth masonry is uncoursed in the strip foundation.	2
		3) The strip foundation is of RC and resting on soft soil.	1
		4) The foundation is a discontinuous RC beam.	4
		5) The foundation is a discontinuous RC beam and resting on soft soil.	2
		Sub-total (Maximum Total Penalty Points is 5)	
iii)	Architecture Features and Elements	a) Plan Shape	
		1) The sizes of the rooms are large, that is, _____.	5
		2) The rooms are oriented irregularly.	3
		3) The overall shape of the building is complex, with reentrant corners.	5
		b) Elevation profile	
		1) The building is wider at the top.	5
		2) The building is heavier at the top.	5
		3) The building has large projections and overhangs, that is, _____.	3
		4) The building has a split roof.	5
		5) The building has large storey heights, that is, _____.	5
		6) The building has different storey heights, that is, _____.	5
		7) The location of staircase is unsymmetrical in the plan of the building.	5

		c) Openings	
		1) The building has a rare single window close to corners.	1
		2) About half of openings in the building are close to the corners.	2
		3) Almost all openings in the building are close to the corners.	4
		4) The window openings are large in size, that is, _____.	4
		5) The door openings are large in size, that is, _____.	6
		d) Distance from adjacent building	
		1) The building touches an adjoining building.	3
		2) The building is at a small distance from an adjoining building, that is, _____.	6
		e) Parapets and objects on roof, and projections	
		1) The projections and overhangs are not secured to the structural system.	10
		2) The projections and overhangs are large and heavy.	10
		f) Staircases	
		1) The staircase is narrow.	1
		2) The staircases are too few for the footprint of the building.	2
		3) The staircases are too far to reach.	3
		4) The staircase is poorly constructed.	4
		g) Water tanks	
		1) The water tanks on rooftop are large in size, that is, _____.	1
		2) The water tanks are placed in the middle of the rooms.	2
		3) The water tanks are not anchored to the structural system.	6
		h) Number of storeys	
		1) 3 – 4 storeys	2
		2) 5 storeys or more	5
		Sub-total (Maximum Total Penalty Points is 20)	
iv)	Structural Aspects	a) Structural walls	
		1) The load paths are indirect or limited.	8
		2) The walls have large openings.	4
		3) The walls are placed unsymmetrical along one plan direction.	3
		4) The walls are placed unsymmetrical along both plan directions.	6
		5) The walls are thick and were constructed in two distinct wythes.	10
		b) Roof design	
		1) The roof is heavy.	4
		2) The roof is pitched without a perimeter frame.	4

		3) The roof is a split roof.	4
		4) The roof is a tiled roof or made of separate planks.	4
		5) The cut-outs in the roof are large.	4
		c) Foundation-wall connection	
		1) The wall reinforcement is not anchored in the foundation.	5
		d) Wall-wall connection	
		1) The roof is pitched but there is no gable band.	4
		2) The roof is hipped but there is no eaves band.	4
		3) There is no lintel band.	8
		4) There is no sill band.	4
		5) There is no plinth band.	2
		6) The arches or vaults do not have tie rods.	8
		e) Wall-Roof and Wall-Floor connection	
		1) The floors and roof are insufficiently or not anchored into the walls	3
		f) Staircase	
		1) The location of the staircase is unsymmetrical.	8
		2) The staircase is integrally built into the building frame both at the top and the bottom.	4
		g) Water Tank on Roof	
		1) The water tank on roof tops is large.	3
		2) The water tank on roof tops is placed unsymmetrically in plan.	5
		Sub-total (Maximum Total Penalty Points is 40)	
v)	Material & Construction Details	a) Materials	
		1) The quality of materials is poor.	15
		b) Workmanship	
		1) The geometries of structural elements is irregular.	3
		2) The walls and roof are cured insufficiently.	10
		3) The procedures of construction are adhoc.	10
		c) Concrete mix	
		1) The concrete is prepared using nominal mix.	2
		2) The ingredients of concrete are measured by volume batching.	3
		Sub-total (Maximum Total Penalty Points is 30)	
		Total Penalty Points	
		EARTHQUAKE FEATURE INDEX = 100 – Total Penalty Points	

Earthquake Feature Index			
MINOR	MODERATE	SEVERE	*Retrofit NOT RECOMMENDED*
Penalty Points < 10	Penalty Points 11 – 40	Penalty Points 41 – 80, OR Penalty Points	Penalty Points 81 – 100 and Total Penalty Points in Structural Aspects > 30

		81 – 100 and Total Penalty Points in Structural Aspects ≤ 30	
Perform at least Level 2 Assessment	*Perform at least Level 3 Assessment*	*Perform Level 4 Assessment*	

7.1.3 *Level 2: Preliminary Quantitative (Hand-Calculation) Evaluation*

The assessment of masonry buildings shall be performed as per **5.1.3** of CED 39 (26741) (Part 1).

The following step-wise procedure shall be adopted to perform this assessment:

a) Estimate the assessment level earthquake base shear force of the building as per **5.4.4.**
b) Estimate:
   1) The total vertical force demand F_{VDi}, and
   2) The total assessment earthquake storey shear force demands F_{HXDi} and F_{HYDi} along X- and Y-directions in plan, respectively,

   at each store i considering the load combinations specified in **5.4.5** for earthquake safety assessment.
c) Distribute the total assessment earthquake base shear forces along the height of the buildings as per **5.2.3.7**(a)(i) of CED 39 (22345).
d) Estimate the storey shear force at each storey of the building as per **5.2.3.7**(a)(ii) of CED 39 (22345).
e) Estimate:
   1) Axial Force Capacity F_{VCi} of all walls and wall pier together at storey i as:

   $$,F_{VCi} = p_{all}A_i$$

   2) Shear Force Capacities F_{HXCi} and F_{HYCi} in walls and wall pier at storey i oriented along X- and Y-directions in plan, respectively, as:

   $$F_{HXCi} = q_{all}A_{Xi} \text{ and } F_{HYCi} = q_{all}A_{Yi}$$

   where A_i is the total area of cross-section of all walls and wall piers together at storey i, A_{Xi} the area of cross-section of all walls and wall piers at storey i oriented along X-direction in plan, and A_{Yi} the area of cross-section of all walls and wall piers at storey i oriented along Y-direction in plan,
f) Check at each storey i, if:

   $$F_{VDi} < F_{VCi}$$
   $$F_{HXDi} < F_{HXCi} \text{ and}$$
   $$F_{HYDi} < F_{HYCi}$$

   If all the above conditions are satisfied, then the building is said to have passed Level 2 Assessment.

7.1.4 *Level 3: Basic Quantitative (Code Compliance) Evaluation*

The assessment of masonry buildings shall be performed as per **5.1.4** of CED 39 (26741) (Part 1).

If all requirements of CED 39 (25408) Sections 1 and 2 are satisfied, then the building is said to have passed Level 3 Assessment.

7.1.5 *Level 4: Detailed Quantitative (Nonlinear) Evaluation*

The assessment of masonry buildings shall be performed as per **5.1.5** of IS 13935 (Part 1).

If all requirements of CED 39 (25408) Sections 1 and 2 are satisfied, then the building is said to have passed Level 4 Assessment.

8 RETROFIT

8.1 Sequence of Interventions

Retrofit of masonry buildings should address first the deficiencies at the structural level and then those at the member level.

a) *Structure level*

Retrofit at the building level is targeted to improve one or all of the following, namely:

1) Overall integrity of the structure, using measures like:
   i) Earthquake bands made either of steel or RC in the form of steel twin-belts or twin-lintel ties lintels, or
   ii) Connections between adjoining walls along the vertical joint, and between walls and roof slab along the horizontal joint.
2) Load Paths in the structure, using measures like:
   i) Enhancing existing load paths in the form of additional structural walls or braces, or
   ii) Creating alternate load paths in the form of buttressing of the deficient building with an adjoining structure built snugly with the deficient structure.
3) Foundations of the structure, using measures like:
   i) Enhancing existing foundations (for example strengthening rubble masonry footings, and enlarging area of RC footing), or
   ii) Strengthening soil under the existing foundation elements (for example underpinning the foundation by drilling micro-piles).

b) *Member level*

Retrofit at the member level is targeted to improve one or all of the following, namely:

1) In roofs and floors of the building:
   i) Diaphragm action using measures like anchorage of reinforcement;
   ii) Connections with walls, using measures like anchorage of reinforcement, screed concrete, or wood planks nailed with cross battens;
2) In columns and piers of the building:
   i) Integrity of the masonry walls, using measures like through stones, and

ii) Jacketing of the masonry member, using measures like jacketing and wrapping.

8.2 Possible Retrofit Schemes

The choice of retrofit depends on available options, feasibility of implementing the retrofit measures, and the cost of retrofit. The spirit of retrofit of masonry buildings is confining them with external and internal supports.

The simplest retrofit alternatives available for masonry buildings are:

a) Addition of horizontal steel twin-belts in brick masonry buildings, and
b) Addition of horizontal steel twin-ties in stone masonry buildings.

A few other alternatives are emerging in the practice. The suitability of such alternatives shall be examined by detailed analytical studies and experimental investigations, and used after quantitative design provisions are approved by the competent authority.

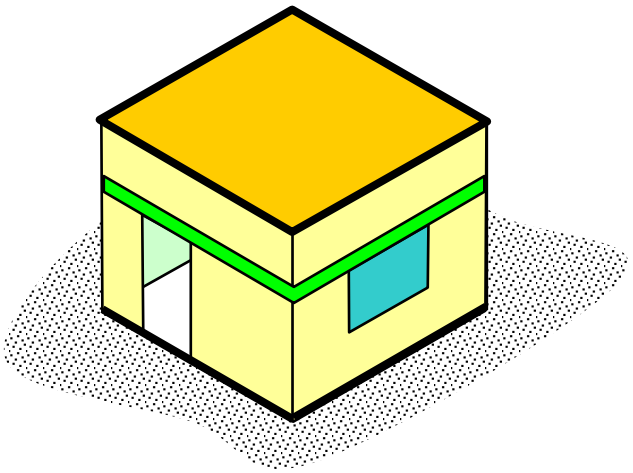
For the building types identified in Table 3 of CED 39 (25408) depending on category of building and earthquake zone, the recommended retrofit alternatives are shown in Table 9 for brick masonry buildings [Fig. 1A and in Table 10 for stone masonry buildings (Fig. 1B].

Table 9 Recommended retrofit measures for Brick Masonry Buildings
(*Clause* 8.2)

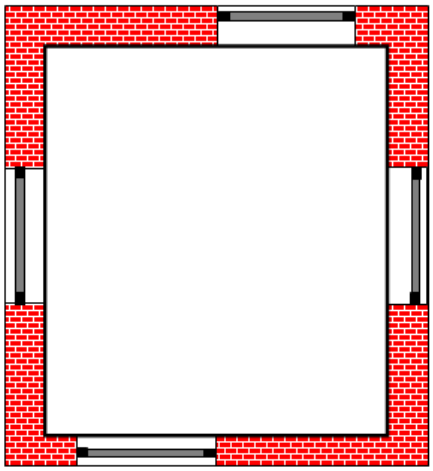
Sl No.	Recommended Retrofit Measure	Types of Buildings			
		B	C	D	E
(1)	(2)	(3)	(4)	(5)	(6)
with Flat Roof					
i)	Steel Twin-Belt Lintel Band only	*Yes*			
ii)	Steel Twin-Belt Lintel and Sill Bands	*Yes*	*Yes*	*Yes*	
iii)	Steel Twin-Belt Lintel and Sill Bands, and Vertical Twin-Reinforcements	*Yes*	*Yes*	*Yes*	*Yes*
with Sloped Roof					
i)	Steel Twin-Belt Lintel Band only	*Yes*			
ii)	Steel Twin-Belt Lintel and Gable Bands	*Yes*	*Yes*		
iii)	Steel Twin-Belt Lintel, Sill, Eaves and Gable Bands	*Yes*	*Yes*	*Yes*	
iv)	Steel Twin-Belt Lintel, Sill, Eaves and Gable Bands, and Vertical Steel Twin-Reinforcements	*Yes*	*Yes*	*Yes*	*Yes*
with Hipped Roof					
i)	Steel Twin-Belt Lintel Band only	*Yes*			
ii)	Steel Twin-Belt Lintel and Eaves Bands	*Yes*	*Yes*		
iii)	Steel Twin-Belt Lintel, Sill and Eaves Bands	*Yes*	*Yes*	*Yes*	
iv)	Steel Twin-Belt Lintel, Sill and Eaves Bands, and Vertical Steel Twin-Reinforcements	*Yes*	*Yes*	*Yes*	*Yes*

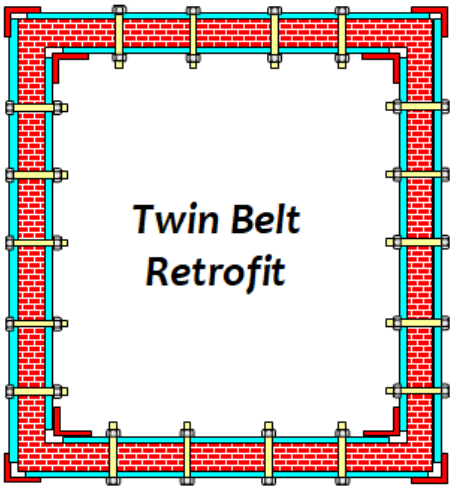
Table 10 Recommended Retrofit Measures for Stone Masonry Buildings
(*Clause* 8.2)

Sl No.	Recommended Retrofit Measure	Types of Buildings			
		B	C	D	E
(1)	(2)	(3)	(4)	(5)	(6)
with Flat Roof					
i)	Steel Twin-Belt Lintel Tie only	Yes			
ii)	Steel Twin-Belt Lintel and Sill Ties	Yes	Yes	Yes	
iii)	Steel Twin-Belt Lintel and Sill Ties and Vertical Steel Twin-Anchors	Yes	Yes	Yes	Yes
with Sloped Roof					
i)	Steel Twin-Belt Lintel Tie only	Yes			
ii)	Steel Twin-Belt Lintel and Gable Ties	Yes	Yes		
iii)	Steel Twin-Belt Lintel, Sill, Eaves and Gable Ties	Yes	Yes	Yes	
iv)	Steel Twin-Belt Lintel, Sill, Eaves and Gable Ties, and Vertical Steel Twin-Anchors	Yes	Yes	Yes	Yes
with Hipped Roof					
i)	Steel Twin-Belt Lintel Tie only	Yes			
ii)	Steel Twin-Belt Lintel and Eaves Ties	Yes	Yes		
iii)	Steel Twin-Belt Lintel, Sill and Eaves Ties	Yes	Yes	Yes	
iv)	Steel Twin-Belt Lintel, Sill and Eaves Ties, and Vertical Steel Twin-Anchors	Yes	Yes	Yes	Yes



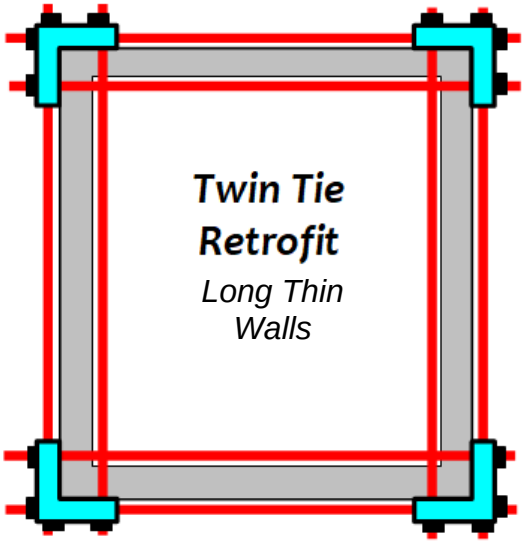
Brick Masonry House

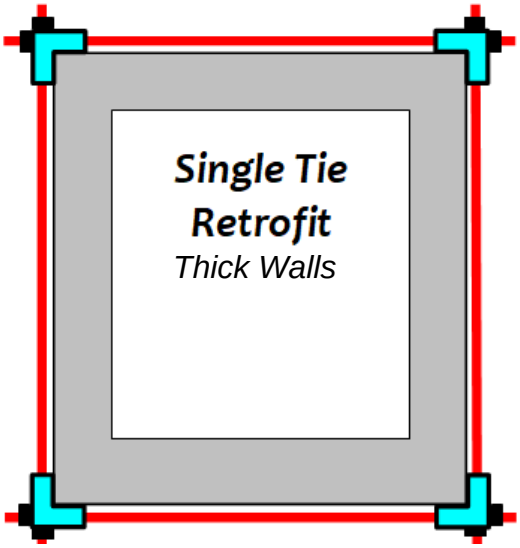




1A

Stone Masonry House





1B

Fig. 1 Retrofitting masonry buildings requires care – reversible retrofit is possible and should be ensured

8.3 Quantitative Verification of Retrofit Schemes

The efficacy of the retrofit schemes shall be demonstrated by estimating the increase in the lateral resistance of the masonry buildings, as per provisions given hereunder.

The following step-wise procedure shall be employed for estimating the increase in the lateral resistance of a masonry building:

a) Estimate the assessment level earthquake base shear force demands F_{HXD} and F_{HYD} along X- and Y-directions in plan, respectively, as per **7.1.3** (b)(2);
b) Estimate the earthquake base shear force (resistance) capacities F_{HXD} and F_{HYD} along X- and Y-directions in plan, respectively, offered only by the retrofit measures as:

$$F_{HXC} = 0.6 f_y \left(\sum_{i=1}^{N_{wX}} A_{RX,i} \right) \; and$$

$$F_{YXC} = 0.6 f_y \left(\sum_{j=1}^{N_{wY}} A_{RY,j} \right)$$

,

where,

f_y = Characteristic Strength of steel used in making the twin-belts or twin-ties,
$A_{RX,i}$ = Cross-sectional area of steel twin-belt or twin-tie i oriented along X-direction in the ground storey,
$A_{RY,j}$ = Cross-sectional area of steel twin-belt or twin-tie j oriented along Y-direction in the ground storey,
N_{wX} = Number of masonry walls oriented along the X-direction in plan, and
N_{wY} = Number of masonry walls oriented along the Y-direction in plan.

9 STRUCTURAL REPAIR OF DAMAGE

Structural members that are damaged shall be repaired during retrofit, to ensure that the member does not deteriorate faster over time.

9.1 Distressed Structural Elements

The distressed structural elements in masonry buildings should be identified through field inspection of the building. The elements of masonry buildings that are likely to deteriorate are:

a) Masonry units,
b) Mortar,
c) Floors and Roof,
d) Walls, and

e) Foundation.

9.2 Structural Repairs

The possible repairs of the distresses in masonry buildings are:

a) Stitching of cracks in walls, and subsequent grouting,
b) Reconstructing locally the parts of the walls, floors, roof or foundations that are crushed or severely cracked. and
c) Re-pointing the joints.

SECTION 3 ADDITIONAL PRINCIPLES FOR CONCRETE BUILDINGS

10 ASSESSMENT

10.1 The method of assessment is applicable to the concrete buildings:

a) With infill masonry made of any material, and
b) With no infill masonry.

10.2 Levels of Assessment

Buildings shall be assessed as per the telescopic method specified in **5.1** and Fig. 1 of CED 39 (26741) (Part 1). The use of Level 0 Assessment for movement to the higher levels of assessment also shall be guided by the said provision.

10.2.1 *Level 0: Basic Prioritization*

The basic information of a concrete building shall be recorded as per Table 11. The impact of the basic prioritization as low, medium and high shall be taken as per Table 1 of CED 39 (26741) (Part 1).

10.2.2 *Level 1: Field Assessment*

The field assessment of a concrete building shall be performed as per:

a) Table 12 for examining life threatening factors, and
b) Table 13 for examining economic loss inducing factors.

Table 11 Basic Information of RC Buildings to be ascertained for Level 0 Assessment
(*Clause* 10.2.1)

TYPE	**DETAILS**		
(1)	(2)		
Inspection Team	Identification	Date	Time
	Inspector 1	Inspector 2	Inspector 3
Building Identity	Building Name	Address	Coordinates
			*N*_____^{o} *E*_____^{o}
Structural System	Frame without or with Structural Walls *(Tick ONE)*	☐ *Moment Frame*	☐ *Others (Please describe)* _____
		☐ *Moment Frame with Structural Walls*	
		☐ *Moment Frame with Braces*	
Structural Components	Floor System *(Tick ONE)*	☐ *RC Slab*	☐ *Others (Please describe)* _____
		☐ *Timber Planks & Beams*	
	Roof System *(Tick ONE)*	Material	Geometry
		☐ *In-situ RC Slab*	☐ *Flat*
		☐ *Precast RC Slab without in-situ screed*	☐ *Pitched*
		☐ *Precast RC Slab with in-situ screed*	☐ *Hipped*
		☐ *Wood Planks*	☐ *Others (Please describe)* _____
		☐ *Steel Truss with Corrugated Sheeting Roof*	
		☐ *Others (Please describe)* _____	
Occupancy *(Tick ONE)*	Residential	☐ *Individual House*	☐ *Apartment*
	Educational	☐ *School*	☐ *College*
		☐ *Institute or University*	
	Lifeline	☐ *Hospital*	☐ *Police Station*
		☐ *Fire Station*	☐ *Power Station*
		☐ *Water Plant*	☐ *Sewage Plant*

	Commercial	☐ *Hotel*	☐ *Shopping*
		☐ *Recreational*	
	Office	☐ *Government*	☐ *Private*
	Mixed Use	☐ *Residential-Commercial*	☐ *Residential-Industrial*
	Others	☐ *Please describe* _____	

Basic Prioritization			
			Priority
i) The structure was designed originally to resist earthquake effects, but			
a)	The structure is being modified to carry heavier loading	☐ *Yes*	Low
		☐ *No*	
b)	Standard is revised and the provisions are more stringent related to: 1) Design earthquake hazard, and/or 2) Design and detailing of structures	☐ *Yes*	Medium
		☐ *No*	
c)	Structure is being extended and/or modified	☐ *Yes*	Medium
		☐ *No*	
d)	The structure is damaged (not by an earthquake) and/or deteriorated substantially	☐ *Yes*	High
		☐ *No*	
ii) The structure was not designed originally to resist earthquake effects.		☐ *Yes*	High
		☐ *No*	
iii) “No” in all of the above			Low

Table 12 Level 1 Field Assessment of Concrete Buildings for Life Threatening Factors
(*Clause* 10.2.2)

Sl No.	Feature	Parameters (Tick all applicable)	Tag
(1)	(2)	(3)	(4)
i)	Siting and Ground Issues	Building has at least one of the following	
		1) Site is an old failed landslide, fissured land, or cracked river terrace.	Red
		2) Site is a hill slopes or adjacent to hill slopes that is vulnerable to sliding during earthquakes.	Red
		3) Site is adjoining (no gap) or downhill a damaged or tilted building.	Red
		4) Ground is a river terrace that can slide or creep.	Red
		5) Ground is vulnerable to falling debris from uphill.	Yellow
ii)	Soil and Foundation Conditions	Building has at least one of the following	
		1) Soil underneath is likely to undergo uneven settlement.	Red
		2) Soil underneath is susceptible to liquefaction.	Red
		3) Soil is weak or non-uniform soil along the long dimension in plan.	Yellow
iii)	Architecture Features and Elements	Building has at least one of the following	
		1) Open storey exists with smaller column size 230mm or less.	Red
		2) Vertical projections or horizontal cantilever balcony or porch is heavy and unanchored.	Red
		3) The adjoining building is damaged.	Red
		4) Water tanks on roof are unanchored.	Red
		5) Plan aspect ratio is more than 5.	Yellow
		6) Outer dimension at plinth level less than that at the roof.	Yellow
		7) Upper storeys are heavier than the lower ones.	Yellow
		8) Plan geometry is irregular.	Yellow
		9) Columns are 230mm thick in a building with more than 3 storeys.	Yellow
		10) Room sizes and storey heights are large.	Yellow
		11) Infill walls are half brick thick.	Yellow
		12) Windows openings are more than 50% of the length of the infill wall.	Yellow
iv)	Structural Aspects	Building has at least one of the following	
		1) Adjoining building is too close and likely to pound with it.	Red
		2) Adjoining building is tilted or unsafe.	Red
		3) Adjoining building has settled unevenly.	Red
		4) RC Structural grid (of columns, beams and walls) is irregular in plan.	Red

		5) Floating columns rest on shallow cantilever beams.	Red
		6) Columns are weaker than the beams framing into them at the joint.	Red
		7) Flat Slabs are used with no structural walls in any plan direction.	Red
		8) Elements of lateral load resisting system (that is moment frame or structural walls) are damaged.	Red
		9) Infill walls are cracked extensively or fallen out of plane.	Red
		10) Some columns have spalling of concrete.	Red
		11) Staircase or stair cabin is damaged.	Red
		12) RC Walls are unsymmetrically positioned along each plan direction.	Yellow
		13) Short columns are present in the plinth or at a higher elevation.	Yellow
		14) Infill walls are separated from the frame, with no damage in columns.	Yellow
		15) RC wall or staircase is unsymmetrically placed in any plan direction.	Yellow
v)	Material & Construction Details	Building has at least one of the following	
		1) The corrosion of reinforcing bars is visible at some places.	Red
		2) There are longitudinal cracks in beams, columns or walls.	Red
		3) The grade of concrete is less than M20.	Yellow
		4) The quality construction is poor.	Yellow
vi)	All	None of the above	Green

RATING		
If GREEN flag only with no RED or YELLOW Flag Perform Level 2 Assessment	If YELLOW flags only with no RED Flag Perform Level 3 Assessment	If at least one RED Flag Perform Level 4 Assessment

SUGGESTED INTERVENTIONS		
Actions		
Building to be SEALED	☐ YES	☐ NO
Building to be DEMOLISHED	☐ YES	☐ NO

Table 13 Level 1 Field Assessment of Concrete Buildings for Economic Loss Inducing Factors
(*Clause* 10.2.2)

Sl No.	Feature	Parameters (Circle all applicable penalty points)	Penalty
(1)	(2)	(3)	(4)
i)	**Siting and Ground Issues**	**a) Building has the following *Siting Issues***	
		1) The house is on sloped ground with access to house at two/three levels, that is ground, middle floor and roof levels.	**5**
		2) The house is built on unstable ground that can slide or liquefy.	**5**
		Sub-Total (Maximum Total Penalty Points is 5)	
ii)	**Soil and Foundation Conditions**	**a) Suitability of Soil**	
		1) The soil is soft soil that is _____.	**2**
		2) The soil is weak soil, that is _____.	**2**
		3) The water table is high, that is _____.	**1**
		4) The soil is moist in most months of the year, that is _____.	**2**
	Foundation	**a) Suitability of Foundation**	
		1) The individual footings are resting on a non-uniform soil with no tie beams.	**4**
		2) The individual footings are resting on a non-uniform soil with tie beams.	**2**
		3) The individual footings are resting on soft soil.	**1**
		Sub-Total (Maximum Total Penalty Points is 5)	
iii)	**Architecture Features and Elements**	**a) Plan Shape**	
		1) The room are large in size, i.e., _____.	**5**
		2) The rooms are oriented irregularly.	**3**
		3) The overall shape of the building is complex, with reentrant corners.	**5**
		b) Elevation Profile	
		1) The building is wider at the top.	**5**
		2) The building is heavier at the top.	**5**
		3) The building has large projections and overhangs, that is, _____.	**3**
		4) The building has a split roof.	**5**
		5) The building has large storey heights, that is, _____.	**5**

		6) The building has different storey heights, that is, _____.	**5**
		7) The location of staircase is unsymmetrical in the plan of the building.	**5**
		8) The building has an open storey.	
		c) Openings	
		1) The openings in concrete walls are large in size, that is, _____.	**6**
		d) Distance from Adjacent Building	
		1) The building touches an adjoining building.	**3**
		2) The building is at a small distance from an adjoining building, that is, _____.	**6**
		e) Parapets and objects on roof, and projections	
		1) The projections and overhangs are not secured to the structural system.	**10**
		2) The projections and overhangs are large and heavy.	**10**
		f) Staircases	
		1) The staircase is narrow.	**1**
		2) The staircases are too few for the footprint of the building.	**2**
		3) The staircases are too far to reach.	**3**
		4) The staircase is poorly constructed.	**4**
		Sub-total (Maximum Total Penalty Points is 30)	
iv)	**Structural Aspects**	**a) Structural system**	
		1) A regular grid is missing of parallel lateral load resisting systems along one of its plan directions.	**5**
		2) A regular grid is missing of parallel lateral load resisting systems along both of its plan directions.	**10**
		3) The stiffness is unsymmetric of the parallel lateral load resisting systems along one of its plan directions.	**5**
		4) The stiffness is unsymmetric of the parallel lateral load resisting systems along one of its plan directions	**10**
		5) The building is made of prestressed members.	**8**
		6) The building has moment frame or moment frame plus wall, but with prestressed floor slabs and/or beams.	**10**
		7) The building has stiff service cores located unsymmetrically in plan.	**15**
		b) Roof design	
		1) The roof or any slab is heavy.	**8**

		2) The roof is pitched without a perimeter frame.	**6**
		3) The roof is a split roof.	**10**
		4) The cut-outs are large in the roof or any floor slab, and close to its edge.	**6**
		c) Member proportioning	
		1) The vertical members are smaller in size than the beams framing into them, with respect to bending about the same axes.	**20**
		d) Connections	
		1) The building is made of precast members that are dry-jointed.	**25**
		2) The building is made of precast members that are wet-jointed.	**5**
		e) Staircase	
		1) The location of the staircase is unsymmetrical.	**8**
		2) The staircase is integrally built into the building frame both at the top and the bottom.	**4**
		f) Water tank on roof	
		1) The water tank on roof tops is large.	**3**
		2) The water tank on roof tops is placed unsymmetrically in plan.	**5**
		Sub-total (Maximum Total Penalty Points is 40)	
v)	**Material & Construction Details**	**a) Materials**	
		1) The quality of materials is poor.	**15**
		b) Workmanship	
		1) The geometries of structural elements is irregular.	**3**
		2) The walls and roof are cured insufficiently.	**10**
		3) The procedures of construction are adhoc.	**10**
		c) Concrete mix	
		1) The concrete is prepared using nominal mix.	**2**
		2) The ingredients of concrete are measured by volume batching.	**3**
		Sub-Total (Maximum Total Penalty Points is 20)	
		Total Penalty Points	
		EARTHQUAKE FEATURE INDEX = 100 – Total Penalty Points	

Earthquake Feature Index			
MINOR	**MODERATE**	**SEVERE**	***Retrofit NOT RECOMMENDED***
Penalty Points < 10	**Penalty Points**	**Penalty Points 41 – 80,**	**Penalty Points 81 – 100** and

	11 – 40	**OR Penalty Points 81 – 100 and Total Penalty Points in Structural Aspects ≤ 30**	**Total Penalty Points in Structural Aspects > 30**
Perform at least Level 2 Assessment	*Perform at least Level 3 Assessment*	*Perform at least Level 4 Assessment*	

10.2.3 *Level 2: Preliminary Quantitative (Hand-Calculation) Evaluation*

The assessment of concrete buildings shall be performed as per **5.1.3** of CED 39 (26741) (Part 1).

The following step-wise procedure shall be adopted to perform this assessment:

a) Estimate the assessment level earthquake base shear force of the building as per **5.4.4.**
b) Estimate:
   1) The total vertical force demand F_{VDi} and
   2) The total assessment earthquake storey shear force demands F_{HXDi} and F_{HYDi} along X- and Y-directions in plan, respectively,

   at each storey i considering the load combinations specified in **5.4.5** for earthquake safety assessment.
c) Distribute the total assessment earthquake base shear forces along the height of the buildings as per **5.2.3.7**(a)(i) of CED 39 (22345).
d) Estimate the storey shear force at each storey of the building as per **5.2.3.7**(a)(ii) of CED 39 (22345).
e) Estimate:
   1) Axial Force Capacity $F_{VCi}$of all columns and structural walls at storey i as per CED 39 (25408) Section 3;
   2) Shear Force Capacities F_{HXCi} and F_{HYCi} of all columns and structural walls at storey i oriented along X- and Y-directions in plan, respectively, as per CED 39 (25408) Section 3;
f) Check at each storey i, if:

$$F_{VDi} < F_{VCi}$$
$$F_{HXDi} < F_{HXCi} \text{ and}$$
$$F_{HYDi} < F_{HYCi}$$

If all the above conditions are satisfied, then the building is said to have passed Level 2 Assessment.

10.2.4 *Level 3: Basic Quantitative (Code Compliance) Evaluation*

The assessment of concrete buildings shall be performed as per **5.1.4** of CED 39 (26741) (Part 1).

If all requirements of CED 39 (25408) Sections 1 and 3 are satisfied, then the building is said to have passed Level 3 Assessment.

10.2.5 *Level 4: Detailed Quantitative (Nonlinear) Evaluation*

The assessment of concrete buildings shall be performed as per **5.1.5** of CED 39 (26741) (Part 1).

If all requirements of CED 39 (25408) Sections 1 and 3 are satisfied, then the building is said to have passed Level 4 Assessment.

11 RETROFIT

11.1 Sequence of Interventions

Retrofit of concrete buildings should address first the deficiencies at the structural level and then those at the member level.

11.1.1 *Structure Level*

Retrofit at the structure level is targeted to improve one or all of the characteristics mentioned hereunder.

a) *Lateral capacity of existing building by addition of new structural elements*

Structural walls and steel bracing shall be added as new elements to increase the strength and stiffness of existing buildings. The deficient buildings may be strengthened through addition of new structural elements by:

1) Addition of new reinforced concrete structural walls involves introducing new structural walls adjoining the frame or infilling the bays between columns and beams with structural walls (Fig. 2).
   It enhances significantly the lateral stiffness and lateral shear force capacity of frame buildings, and provides the best option of strengthening existing buildings for improved earthquake performance.
2) Addition of new steel bracing involves introducing new diagonal steel braces within the select beam-column bays along the full height of the building (Fig. 3). Pre-fabricated steel bracing sub assemblages may be adopted (Fig. 4) for ease of construction, Braces in X, V and inverted V shall be arranged inside a heavy rectangular steel frame, which is then placed in frame bay and firmly connected.
   It enhances significantly the lateral stiffness and lateral shear force capacity of frame buildings, and provides the competitive (speedy) option of strengthening existing buildings for improved earthquake performance.

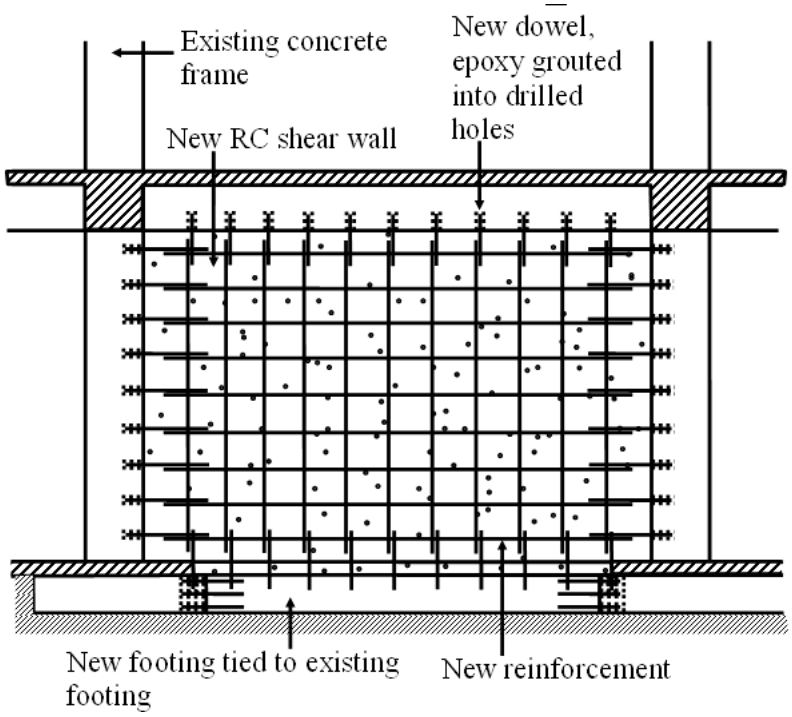
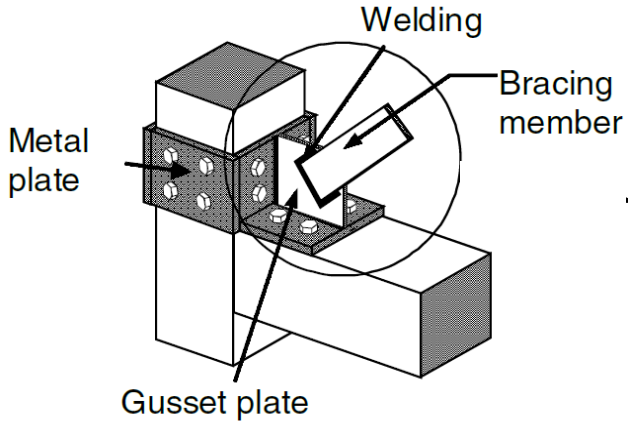
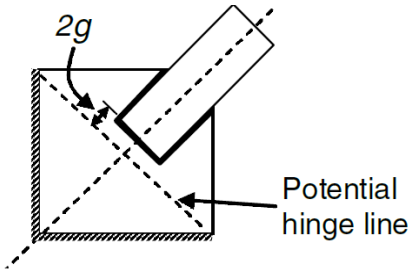


Fig. 2 Adding new RC structural walls within the beam-column bays of RC frame with additional concrete and steel

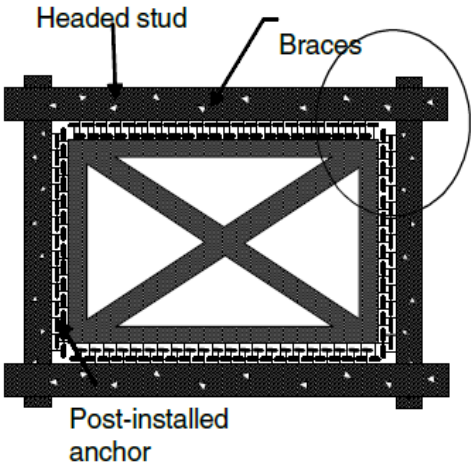


3A Brace connection details

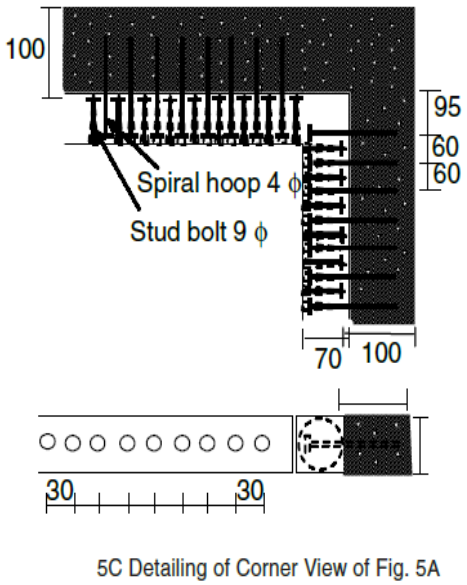


3B Gusset plate connection detail

Fig. 3 Brace connection when adding new steel braces within the beam-column bays of RC frame with additional steel members



4A prefabricated bracing frame



4B corner view of prefabricated bracing frame

Fig. 4 Details of pre-fabricated steel bracing

11.1.2 *Member Level*

Retrofit at the member level is targeted to improve one or all of the characteristics mentioned hereunder.

a) *Capacity of existing columns by Jacketing*

The deficient columns identified during detailed evaluation of building that require enhancement of strength and/or ductility may be jacketed by:

1) Reinforced concrete jacketing involves placement of new longitudinal reinforcement and transverse reinforcement bars in the new concrete overlay around existing member (Fig. 5).

   Reinforced concrete jacketing improves both flexural strength and ductility, and closely spaced transverse reinforcement provided in the jacket improves both shear strength and ductility of the column, if the following are satisfied:
   i) The jacketing is started from the foundation level to the level up to the height of the column which is being retrofitted.
   ii) The foundation of the existing column is enhanced by extending and integrating the added part with the existing one.

   Else, it improves only the ductility of the existing column.
2) Steel profile jacketing or steel encasement involves placement of steel angles at each corner of the existing reinforced concrete member and connected together as a skeleton with transverse steel straps. Another way is by providing steel encasement. And, steel encasement is the complete covering of the existing member with thin plates; and
3) Wrapping with FRP sheets involves placement of composite material made of continuous fibers with resin impregnation on the outer surface of the reinforced concrete member.

Where possible, the deficient members shall first be stress relieved by propping before jacketing.

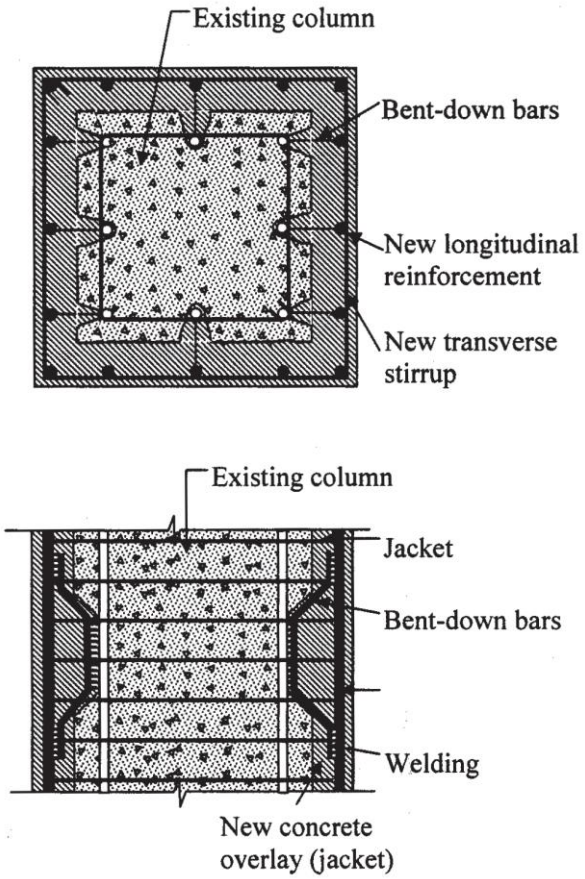


Fig. 5 Jacketing of existing columns with jacketing with new concrete and additional steel

11.3 Quantitative Verification of Retrofit Schemes

The choice of retrofit of concrete buildings depends on available options, feasibility of implementing the retrofit measures, and the cost of retrofit. The spirit of retrofit of masonry buildings is confining them with external and internal supports.

The simplest retrofit alternatives available for concrete buildings are:

a) Addition of structural walls, and
b) Addition of braces.

A few other alternatives are emerging in the practice. The suitability of such alternatives shall be examined by detailed analytical studies and experimental investigations, and used after quantitative design provisions are approved by the competent authority.

The said alternative retrofit schemes are within the realm of engineering calculations. The increase in the lateral resistance of the concrete buildings shall be estimated with the retrofit scheme in place hereunder. Here, the design of the new RC structural walls shall be performed as per CED 39 (25408) Section 3 and of the new steel braces as per CED 39 (25408) Section 4.

12 STRUCTURAL REPAIR OF DAMAGE

Structural members that are damaged shall be repaired during retrofit, to ensure that the member does not deteriorate faster over time.

12.1 Distressed Structural Elements

The distressed structural elements should be identified through field inspection of the building. The elements of concrete buildings that are likely to deteriorate are:

a) Beams,
b) Columns and Walls,
c) Floors and Roof,
d) Infill Walls, and
e) Foundation.

12.2 Structural Repairs

The possible repairs of the distresses in concrete buildings are:

a) Grout of cracks in beams, columns and RC walls,
b) Reconstructing locally the parts of the beams, columns, walls, floors, roof or foundations that are crushed or severely cracked, and
c) Stitching of infill walls, and subsequent grouting.

ANNEX A

(*Clause* 2)

LIST OF REFERED STANDARDS

IS No.	*Title*
IS 456 : 2000	Plain and reinforced concrete (*fourth revision*)
IS 800 : 2007	General construction in steel (*second revision*)
IS 875	Design loads (other than earthquake) for buildings and structures:
Part 1 : 1987	Dead loads (*second revision*)
Part 2 : 1987	Imposed loads (*second revision*)
Part 3 : 2015	Wind loads (*third revision*)
Part 4 : 1987	Snow loads (*second revision*)
Part 5 : 1987	Special loads and load combinations (*second revision*)
IS 1343 : 2017	Prestressed concrete (*second revision*)
CED 39 (22343)	Design earthquake hazard and criteria for earthquake resistant design of structures Part 1 General Provisions (*seventh revision*)
CED 39 (22345)	Design earthquake hazard and criteria for earthquake resistant design of structures Part 2 Buildings (*seventh revision*)
IS 1905 : 1987	Structural use of unreinforced masonry (*third revision*)
CED 39 (25407)	Earthquake resistant design and detailing of structures Part 1 General provisions (*second revision*)
CED 39 (25408)	Earthquake resistant design and detailing of structures Part 2 Buildings (*second revision*)
CED 39 (26741)	Earthquake safety assessment and retrofitting of structures Part 1 General provisions (*second revision*)

ANNEX A
(*Foreword*)

(*Composition of the Committee will be added after finalization*)

****