Home Owner's Guide

for Earthquake and Cyclone Safety

September 2019

National Disaster Management Authority
Ministry of Home Affairs
Government of India

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A publication of:

National Disaster Management Authority
Ministry of Home Affairs
Government of India
NDMA Bhawan
A-1, Safdarjung Enclave
New Delhi – 110 029

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सत्यमेव जयते

प्रधान मंत्री
Prime Minister

MESSAGE

It is a pleasure to learn that the National Disaster Management Authority (NDMA) is coming out with a Home Owner's Guide for earthquake and cyclone safety. The objective of this Guide is to enhance the safety and security of our homes. It outlines simple measures and tips that must be considered while buying, or moving into a new house.

This Home Owner's Guide contains practical suggestions to safeguard one's home against earthquakes, cyclones and such disasters at the time of construction of houses. The instructions in this Guide have taken into account the differing topographic and geographic variations across the country.

The damage inflicted by disasters can be minimized by enhancing the structural resilience of our homes. Simple, well-illustrated guidelines will be a reliable storehouse of information on making our homes disaster resistant.

I am sure that people will refer to this Home Owner's Guide in large numbers and help in making our nation resilient to disasters.

Best wishes to the NDMA for the thoughtful initiative of bringing out the Home Owner's Guide.

(Narendra Modi)

New Delhi
श्रावण 29, शक संवत् 1941
20th August, 2019

अमित शाह
AMIT SHAH

गृह मंत्री
भारत
HOME MINISTER
INDIA

सत्यमेव जयते

संदेश

मुझे यह जानकर प्रसन्नता हो रही है कि राष्ट्रीय आपदा प्रबंधन प्राधिकरण (एन.डी.एम.ए) ने भवन मालिकों को भूकंप तथा चक्रवात का सामना करने में समर्थ तकनीक के अनुसार अपने भवनों का निर्माण करने में सहायता देने हेतु दिशा-निर्देश तैयार किये हैं।

हमारी अर्थव्यवस्था तीव्र गति से विकास कर रही है, और हम अधिक से अधिक भवनों का निर्माण कर रहें हैं। यह महत्वपूर्ण है कि हम इन भवनों का निर्माण आपदाओं का सामना करने में सक्षम तकनीक और उन्हें अधिक से अधिक टिकाऊ बनाने वाले उपायों से करें ताकि किसी आपदा के कारण होने वाली जान-माल की हानि में कमी आए। इस प्रकार समय के साथ-साथ, आर्थिक हानियों को रोकने से लोगों का जीवन-स्तर और बेहतर बनेगा।

यह दिशा-निर्देश निर्माण के संपूर्ण चक्र-ग्रामीण, शहरों के रूप में विकसित हो रहे ग्रामीण इलाकों तथा शहरी इलाकों में मकानों के साथ-साथ चिनाई वाली तथा प्रबलित कंक्रीट इमारतों को शामिल करता है और लोगों को आपदा का सामना करने में सक्षम भवनों को बनाने/खरीदने के बारे में उचित जानकारी तथा सभी जरूरी प्रश्नों के जवाब उपलब्ध कराता है। इस दिशा-निर्देश का उपयोग किसी भवन को बनाते/खरीदते समय आम गलतियों को करने से बचने के लिए किया जा सकता है।

मैं, एक खुशहाल एवं तनाव-मुक्त कल के लिए, संभावित भवन-मालिकों से इन दिशा-निर्देशों का संदर्भ लेने का आग्रह करता हूँ।

शुभकामनाओं सहित !

(अमित शाह)

Office : Ministry of Home Affairs, North Block, New Delhi-110001
Tel : 23092462. 23094686, Fax : 23094221
E-mail : hm@nic.in

सत्यमेव जयते

Foreword

India is prone to various natural hazards, including low frequency but high impact hazards which have a high damage potential. It is evident from the past experiences that unsafe buildings cause major damages during disasters adversely affecting lives, livelihoods and property. Since such natural hazards are not avoidable, potential losses and damages can be reduced by adopting safe building construction practices. There is an established set of building standards and codes for constructing disaster-resilient houses. However, the need was felt to develop a guide consisting of basic information on essential elements of disaster-resilient houses for homeowners and homebuyers.

This guide provides elementary details on i) selection of suitable site; ii) ideal shape, size and form of the house; iii) quality of building material and its safe storage; iv) basic engineering details to construct a house; and v) engagement of technical professional to design and supervise the house during construction for minimizing the damage during earthquake and cyclone. This guide also encapsulates its essence in a chapter on simple Do's and Don'ts.

The guide will make homeowners aware of various considerations and requirements which need to be taken care of while constructing and buying a house. It would also help them avoid the common mistakes and ask the relevant questions to the engaged professionals or the seller in urban areas to ensure that the house is disaster-resilient.

This guide is easy to understand, and has lucid illustrations and suitable photographs. We hope that this will serve as a ready reckoner for the end users and promote the adoption of best construction practices, which would ultimately lead to disaster risk reduction in the country.

Kamal Kishore
Member, NDMA

Dr. D. N. Sharma
Member, NDMA

Lt. Gen. N C Marwah (Retd)
Member, NDMA

G V V Sarma, IAS
Member Secretary, NDMA

Preface

This *Home Owner's Guide* is prepared with *Earthquake* and *Cyclone* hazards in mind, and is expected to guide potential home owners towards reducing potential losses in future in the aftermath of the negative fallout of these natural events. It provides details to those who are *constructing* a house and who are *buying* a flat in multi-storey buildings, which are made of either *masonry* or *reinforced concrete* (*RC*). This *Guide* focuses to address this aspiration of potential home owners, and provides the basic information that they should have when *constructing individual houses* or *buying flats in multi-storey buildings*.

This *Guide* provides the basic information on *five* aspects related to construction or purchase of a house, namely:

(1) *Site* – Suitable Site to Construct a House,
(2) *Form* – Appropriate Geometry and Sizing of a House,
(3) *Materials* – Quality of Materials for Constructing a House,
(4) *Technical Details* – Special Engineering Details of a House, and
(5) *Professionals & Artisans* – Competent Hands to Construct a House.

The aspects mentioned in this Guide are the *minimum requirements* that have to be complied with while constructing a house; this select information is in no way to be considered either *comprehensive* or *complete*. The *Guide* is intended to reduce the most commonly made mistakes while constructing houses. Cartoon characters, *Dadaji* and *Munni*, used in the illustrations, walk potential readers of the *Guide* through the *good practices*.

The development of *an individual house* or *a multi-storey building with many flats* in each of them requires attention to *siting*, *planning*, *designing*, *constructing*, *maintaining* and *retrofitting*. This *Guide* addresses only aspects related to *siting*, *planning*, *designing* and *constructing* of houses. Even these four aspects are dealt with a limited scope of informing the *Home Owners* of the essential information that they need to possess before constructing or buying a house. Thus, this *Guide* is in no way complete with all details that professionals may need to *site*, *plan*, *design* and *construct* houses.

The contents of this *Guide* are scripted by *C. V. R. Murty* and *Rupen Goswami* of IIT Madras, and illustrated by *Rajkumar Patel* of Government Polytechnic College, Alwar. This *Guide* is prepared under the aegis of the *National Disaster Management Authority*, Government of India.

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How to use this Guide

This *Home Owner's Guide* is useful for two sets of readers, namely:

(1) Those who wish to *construct* a house, and
(2) Those who wish to *buy* a *house* or a *flat* in a multi-storey building.

Those who wish to *construct* a house should read *all* pages of this *Guide*, and follow step by step each item given in *Section 1* to *Section 5*. And, those who wish to *buy* a *house* or a *flat* in a multi-storey building should read specifically *Sections 1* and *5*; this will enable them to ask the *Seller* relevant questions related to: (a) *legality* of the land on which the house is to be built, (b) *safety* of the structure of the house to withstand earthquakes and cyclones, and (c) *quality* of the house or flat being purchased. But, even when they are just buying a *house* or a *flat*, it will be beneficial if they can read *Sections 2*, *3* and *4* also.

The current trend indicates that two types of construction are dominant across the country, namely:

(1) Individual Houses made of *unreinforced masonry walls* and *RC floor & roof slab*s, and

(2) Multi-storey Buildings made of *RC frame system (with beam, columns and floor & roof slab*s made of RC) with *unreinforced masonry infill walls* to make distinct functional spaces.

These are built in *rural*, *rurban* and *urban* areas across the country. Irrespective of which municipal area the houses are built in, the technical aspects remain the same. Hence, this *Guide* does not make any distinction of construction of houses in these three sets of municipal areas. Thus, all sections of the Guide are relevant in all three areas – *rural*, *rurban* and *urban*.

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Acknowledgements

Earthquakes and Cyclones disrupt *lives*, *livelihoods* and *infrastructure*. Preventing them from affecting *dwelling units* is a *small* yet significant step towards building disaster resilience. The continued support of *Sri G. V. V. Sarma*, Member-Secretary, NDMA, *Lt.Gen. N. C. Marwah (Retd.)*, *Dr. D. N. Sharma* and *Sri Kamal Kishore*, Members, NDMA, and *Dr. Pradeep Kumar*, the then Secretary In-charge, NDMA, was crucial in the timely completion of this *Guide*.

NDMA acknowledges the contribution of the authors of this *Guide*, *Professors C. V. R. Murty* and *Rupen Goswami* of IIT Madras, and *Sri Rajkumar Patel*, Government Polytechnic College, Alwar.

Dr. V. Thiruppugazh, Joint Secretary (Policy and Plan), NDMA, has played a *key role* in conceptualising and finalising this Guide. *Sri Nawal Prakash*, Senior Research Officer, NDMA, and *Sri Mahendra Meena*, Consultant (Earthquake), NDMA, have provided technical and administrative support.

Indian Institute of Technology Jodhpur and *Indian Institute of Technology Madras* provided administrative support in the development of this *Guide*; NDMA gratefully acknowledges the same.

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Contents

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Hazards in Focus

Hazards in Focus

This *Guide* addresses two natural hazards, namely *Earthquakes* and *Cyclones*. These hazards were mapped by:

(1) *Earthquake Hazard:* the *Bureau of Indian Standards*, Ministry of Consumer Affairs, Food & Public Distribution, Government of India, based on scientific work of the *India Meteorological Department*, Ministry of Earth Sciences, Government of India, and the *Geological Survey of India*, Ministry of Earth Sciences, Government of India.

(2) *Cyclone Hazard:* the *Survey of India (SoI)*, Department of Science & Technology, Government of India, based on scientific work undertaken by the *SoI* and the *India Meteorological Department*, Ministry of Earth Sciences, Government of India.

Even though this *Guide* is not prepared to address the effects of natural *Flood* hazard, all the contents of the Guide will be useful in areas where flooding is a concern. This *Flood* hazard was mapped by:

(3) *Flood Hazard:* the *Survey of India*, Department of Science & Technology, Government of India, based on scientific work undertaken by the *SoI* and the *Central Water Commission*, Ministry of Water Resources, Government of India.

The above maps are thematically presented by the *Building Materials and Technology Promotion Council*, Ministry of Housing and Urban Affairs, Government of India, along with the data from *2011 Census of India* provided by the *Office of the Registrar General & Census Commissioner, India*.

Earthquake

As per the Indian Standard IS 1893 (Part 1) : 2016, which deals with earthquake resistant design of buildings and other structures, India's land area is divided into *four Seismic Zones*, namely *Seismic Zones II*, *III*, *IV* and *V*. Intensities of earthquake ground shaking likely to be experienced in the land areas under each of these zones are:

(1) *Seismic Zone II* : *Low intensity* of up to *VI (and lower)* on MSK Scale,
(2) *Seismic Zone III* : *Medium intensity* of about *VII* on MSK Scale,
(3) *Seismic Zone IV* : *Strong intensity* of *about VIII* on MSK Scale, and
(4) *Seismic Zone V* : *Severe intensity* of about *IX (or above)*.

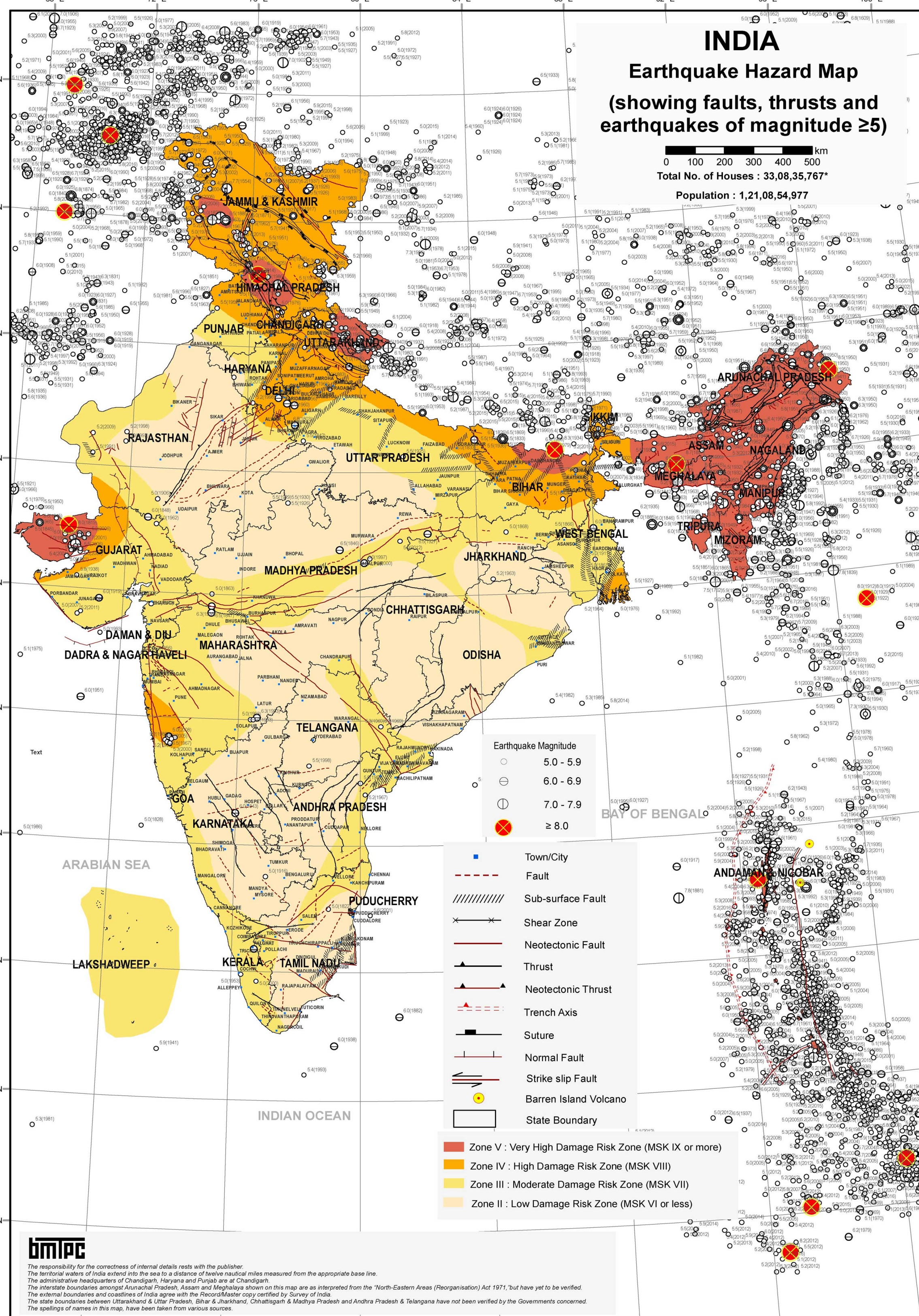
And, as per the *2019 Vulnerability Atlas of India*, India is under extensive *threat* of *Earthquakes*, and is highlighted by the fact that about 57% of the land area of the country lies in Seismic Zones III, IV and V, in which about 79% of the population resides. Most houses constructed so far do not have *all* the necessary earthquake resistant features built in them, especially in Seismic Zones III, IV and V.

Since even areas coming under the *least* hazardous seismic zone, namely *Seismic Zone II*, are expected to experience earthquake shaking, it is best to build houses with earthquake resistant features in them too; of course, the Indian Standards recommend that the key virtues of earthquake resistant construction be included *mandatorily* only in constructions in areas located in *Seismic Zones III*, *IV* and *V*. This *Guide* presents some basic features that houses should possess, along with the process to be adopted in their *design* and *construction*.

National Disaster Management Guidelines – Management of Earthquakes, National Disaster Management Authority, Government of India, April 2007

IS 1893 (Part 1) : 2016, Indian Standard Criteria for Earthquake Resistant Design of Structures: Part 1 – General Provisions and Buildings, Bureau of Indian Standards, New Delhi, Sixth Revision

2019 Vulnerability Atlas of India, Building Materials and Technology Promotion Council, Ministry of Housing and Urban Affairs, Government of India, 2019, Third Edition



BMTPC : Vulnerability Atlas - 3rd Edition : Peer Group, MoHUA, GOI; Map is Based on digitised data of SOI; Seismic Zones of India Map IS 1893 (Part I): 2002, BIS; Earthquake Epicentre from IMD; Seismotectonic Atlas of India and its Environs, GSI; Houses/Population as per Census 2011; *Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

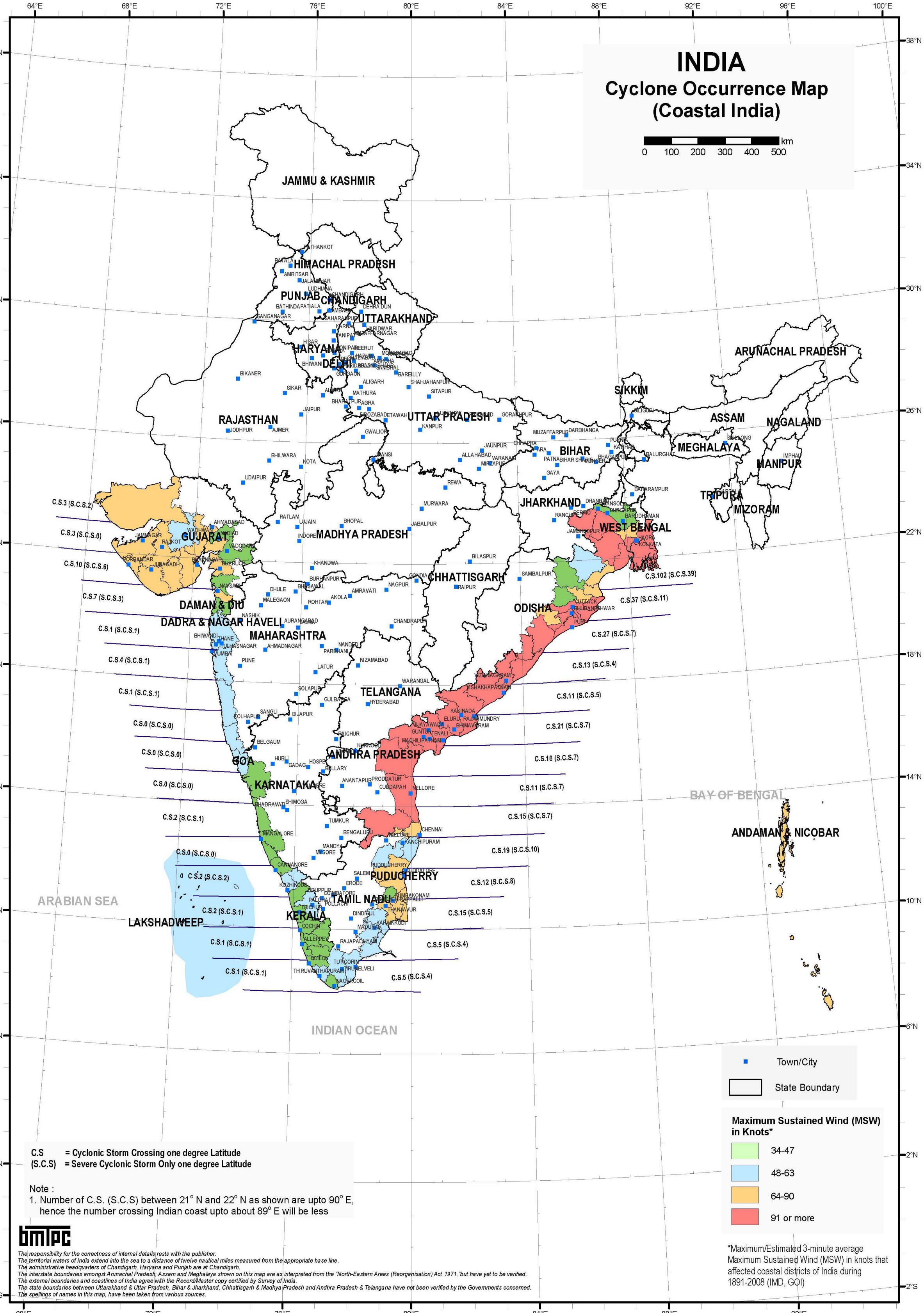
Cyclones

As per the *2019 Vulnerability Atlas of India*, India is under high *threat* of *Floods* arising during *cyclones* also, and is highlighted by the fact that its long flat coastline of about 7,516 km has been extremely vulnerable to cyclones (originating in the *Bay of Bengal* and the *Arabian Sea*) and its associated hazards, like *storm tides* (the combined effects of *storm surges* and *astronomical tides*), high velocity winds and heavy rains. Their impacts on the east coast of India as well as the Bangladesh coast are relatively more devastating. *Thirteen* coastal *States & Union Territories* in the country, encompassing *84 districts*, are affected by tropical cyclones. Five states (*Tamil Nadu*, *Andhra Pradesh*, *Odisha* and *West Bengal* on the east coast, and *Gujarat* on the west coast) and one UT (*Puducherry* on the east coast) are more vulnerable to hazards associated with cyclones. This makes about 8% of the land area and almost a third of the total population of the nation vulnerable to cyclone related hazards. The sea-level rise resulting from climate change effects are expected to significantly increase the vulnerability of the coastal population.

Since flooding is a major feature of *cyclones*, it is best to build houses with their plinths elevated above the *high flood level* in that area in interior areas and above *high water level* in areas along the coastal areas. This *Guide* provides some basic guidelines regarding construction of houses with respect to *heavy winds acting on roofs* (leading to lift off of unanchored light roofs) and *heavy downpour of rain* (leading to flooding of low lying areas) caused during cyclones, which need the attention of the owners during the *design* and *construction* of the houses.

National Disaster Management Guidelines – Management of Cyclones, National Disaster Management Authority, Government of India, April 2008

2019 Vulnerability Atlas of India, Building Materials and Technology Promotion Council, Ministry of Housing and Urban Affairs, Government of India, 2019, Third Edition



BMTPC : Vulnerability Atlas- 3rd Edition; Peer Group, MoHUA; Map is Based on digitised data of SOI, GOI; Maximum Sustained Wind (MSW) Data from IMD, GOI. Disclaimer: The maps are solely for thematic presentation.

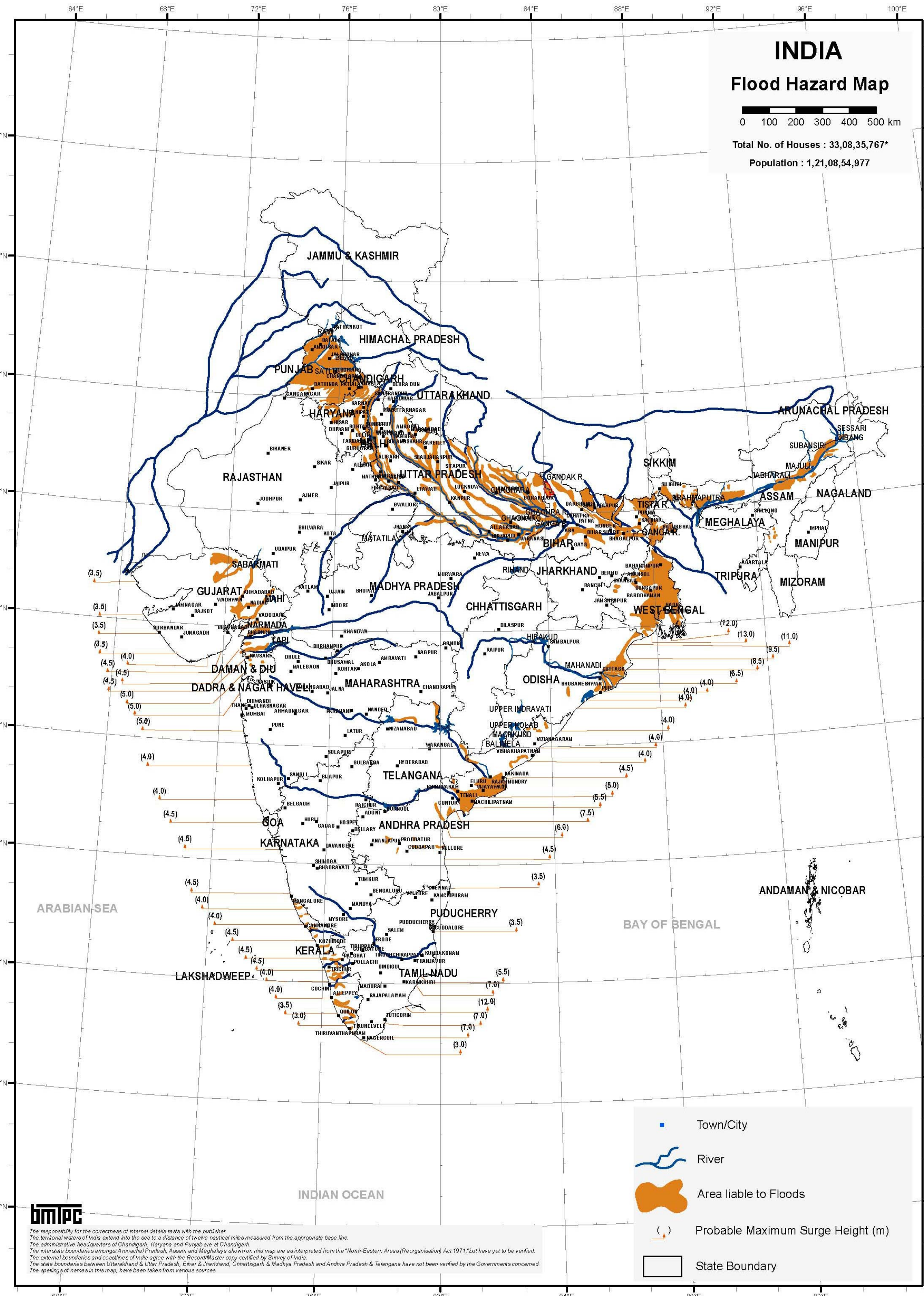
Floods

As per the *2019 Vulnerability Atlas of India*, India is under high *threat* of *Floods* and is highlighted by the fact that about 12% of its land is prone to floods, *i.e.*, about *400 Lakh Hectares* out of a geographical area of *3,290 Lakh Hectares*. On an average every year, about *75 Lakh Hectares* of land is affected. Many houses built so far are in the flood plains of the rivers, which may not have the river protection works along the full length of the river from mountain source to ocean sink. The problem is especially serious along major rivers of the nation. The plinth levels of the houses are at or below the *High Flood Level* (HFL) of the river or its canal. Also, *Floods* are occurring in areas, which were earlier not considered flood prone. Flooding in the *cities and towns* is caused by increasing incidence of heavy rainfall in a short period of time, indiscriminate encroachment of waterways, inadequate capacity of drains and lack of maintenance of the drainage infrastructure. The problem is becoming more severe and losses are mounting every year.

Since water always flows to the lowest elevation in any area, it is best to build houses with their plinths elevated above the HFL of the river or its canal in that area. This *Guide* provides some basic guidelines regarding choosing the sites for constructing houses with respect to flooding, which need the attention of the potential home owners.

National Disaster Management Guidelines – Management of Floods, National Disaster Management Authority, Government of India, January 2008

2019 Vulnerability Atlas of India, Building Materials and Technology Promotion Council, Ministry of Housing and Urban Affairs, Government of India, 2019, Third Edition



BMTPC : Vulnerability Atlas - 3rd Edition; Peer Group, MoHUA; Map is Based on digitised data of SOI, GOI; Census of India 2011; Flood Atlas (1987),Task Force Report (2004), C.W.C., G.O.I. Houses/Population as per Census 2011; * Houses including vacant & locked houses. Disclaimer: The maps are solely for thematic presentation.

1

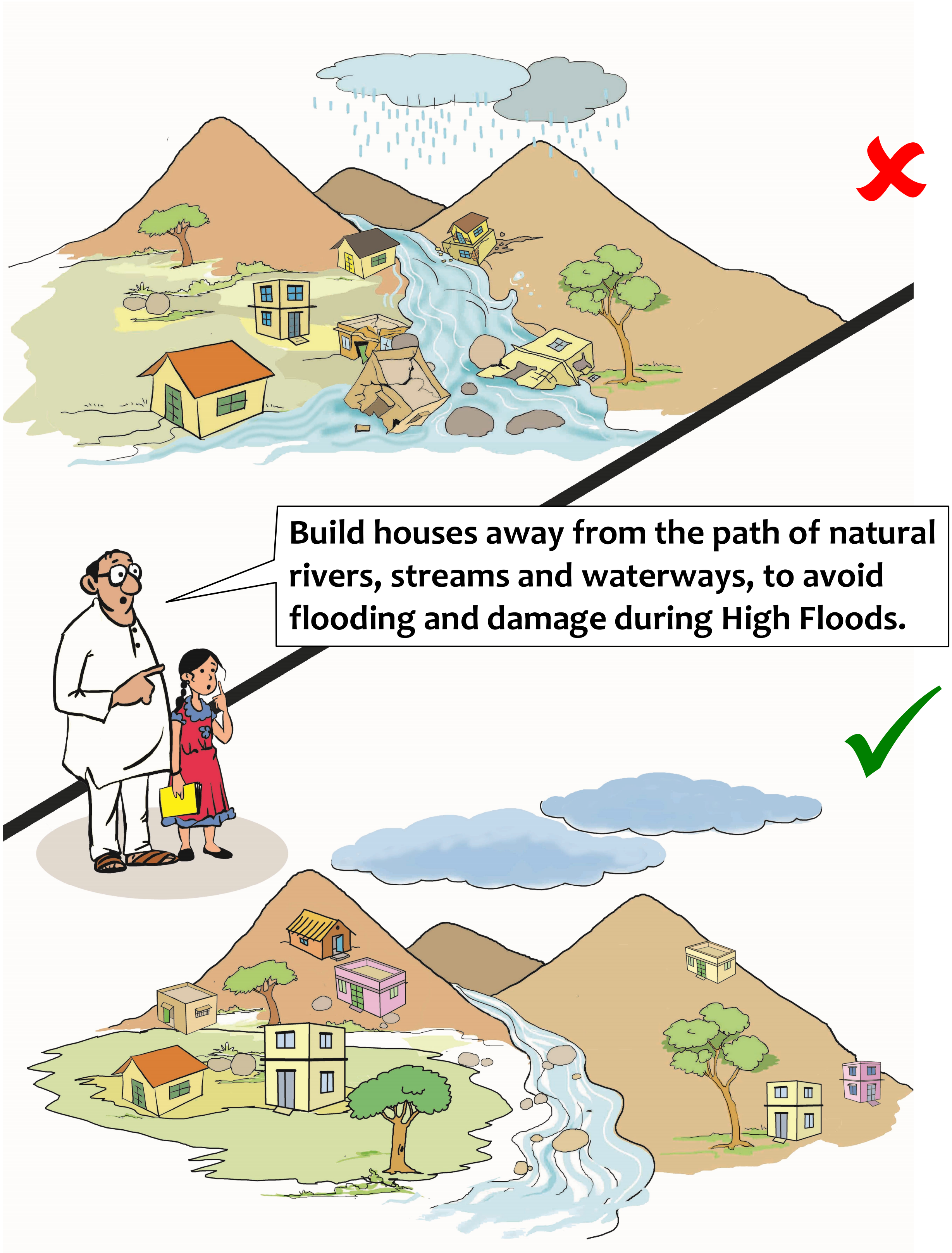
SITE

Suitable Site to Construct a House

Away from Natural Waterways

A house should be constructed on land that is away from the paths along which water flows naturally in the area. These natural waterways are *rivers*, *streams* and *rain water drainage paths*. The site should be at a safe horizontal distance sufficiently away and at an elevation higher than the natural waterway, to avoid flooding and thereby damage to the house during *high floods* either during *annual rains* or *sudden natural events of rain*, especially during *cyclones*.

And, even if the house is built *away* from the natural waterways, its *foundation* should be laid sufficiently below the native ground level, to avoid *scouring* of the soil below the foundation during heavy rains. Also, houses should not be founded on *reclaimed* or *filled soil*, which are *loose*.



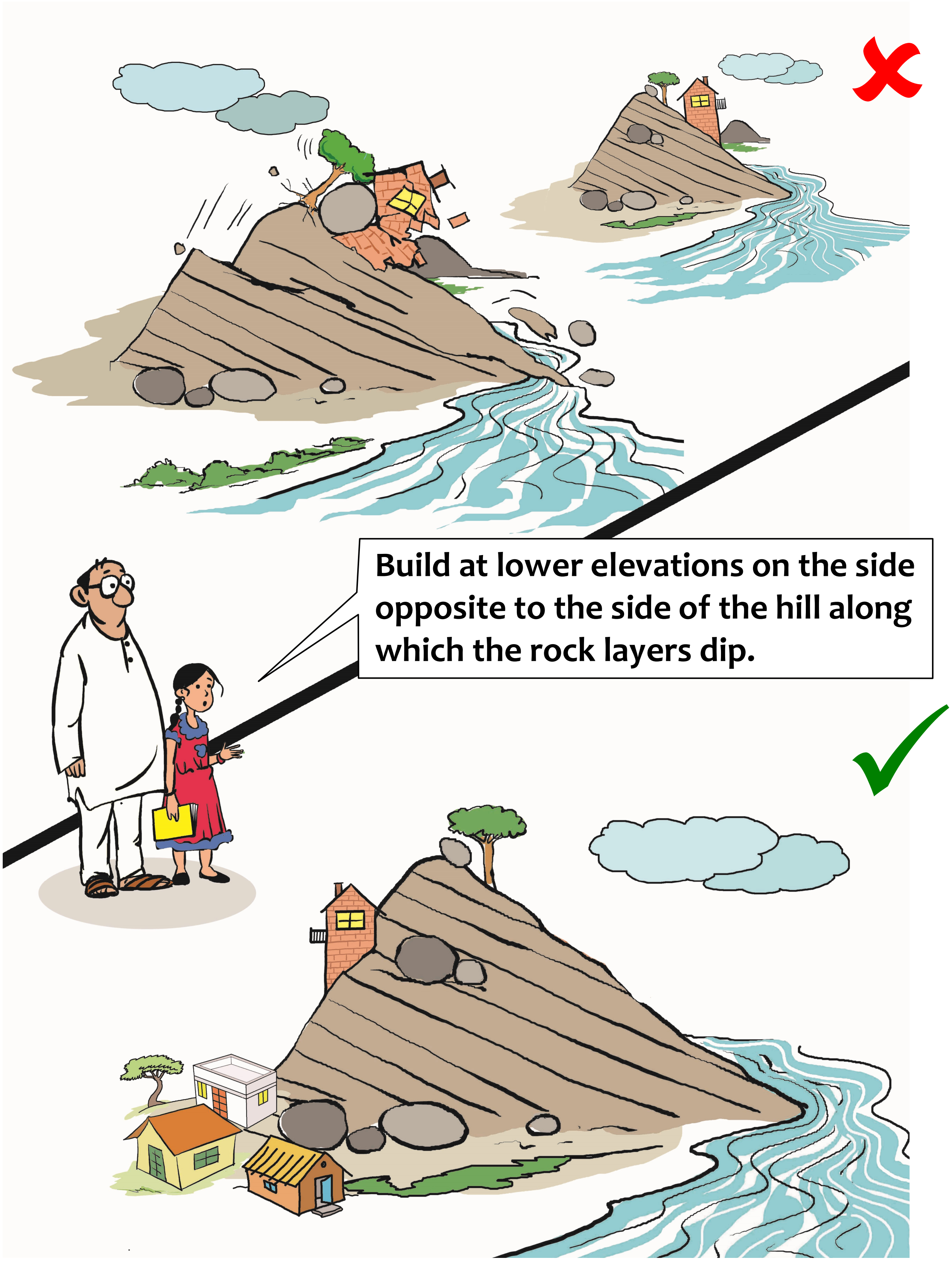
Away from Natural Waterways

Avoid Rocky Hill Slopes

When identifying site to construct a house on rocky hill slopes, the rock layers in the hill should be examined. A house along the hill slope has two threats, namely:

(1) rolling boulders and debris from upper elevations, and
(2) sliding of soil mass above and below the level of the house.

On rocky hill slopes, the side of the hill along which the layers of rock dip is *unsafe* for construction. Under normal conditions, the boulders will keep sliding and rolling downhill on this side of the hill. And, under strong earthquake ground shaking, the rock layers themselves may slide downhill on this side. Thus, it is best to construct on the side *opposite to the side of the hill along which the rock layers dip*, and that too preferably, at lower elevations, to the extent possible.

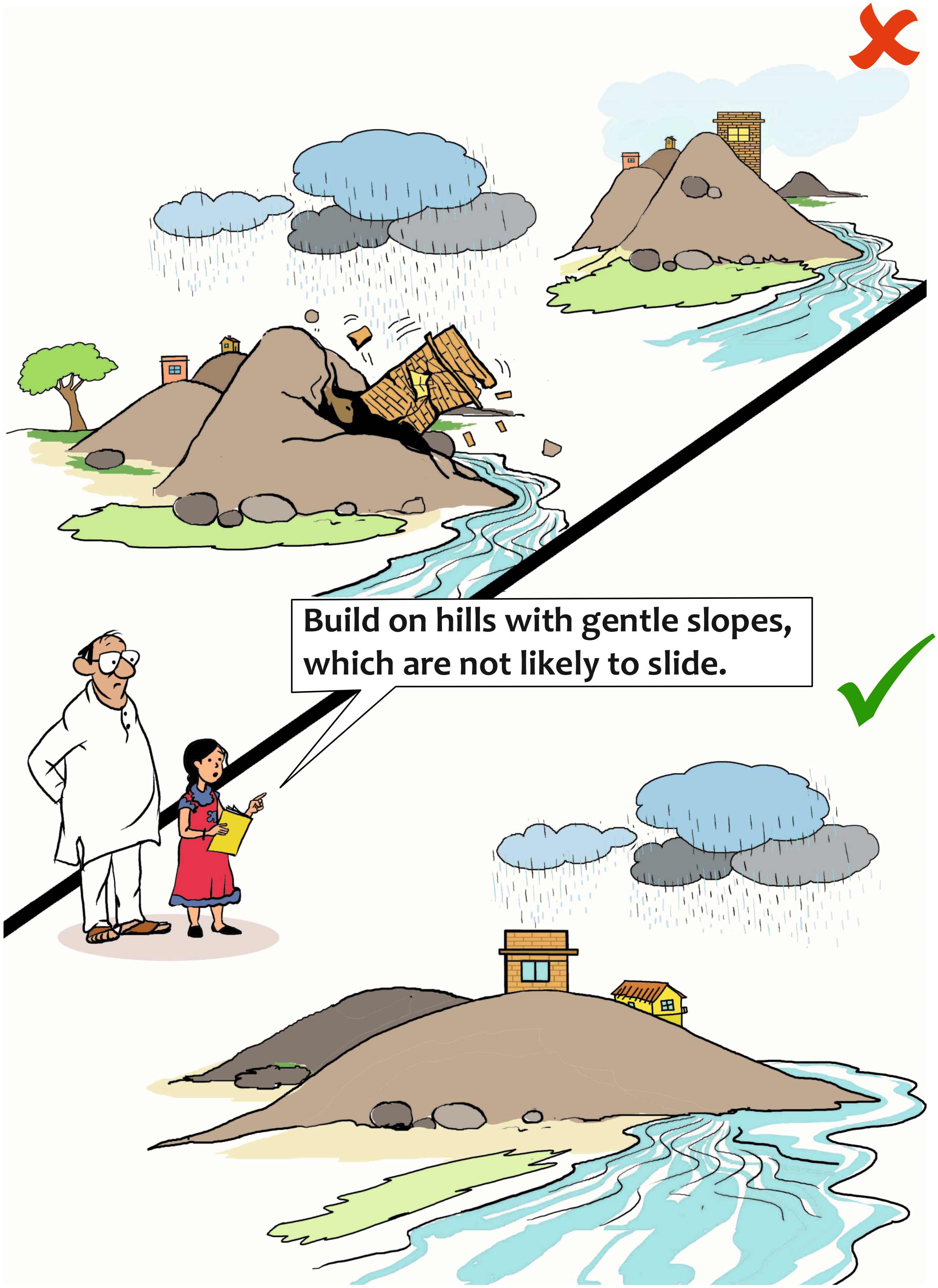


Avoid Rocky Hill Slopes

Build on Gentle Hill Slopes

Part of a soft soil hill has a tendency to slide in large masses. This tendency is more when the hill slopes are *steep*; the critical angle of the hill slope beyond which the chances of sliding are higher depends on the type of soil. Sliding happens when the soft soil *gets moist under rain* or is subjected to *strong earthquake ground shaking*. Therefore, it is best to build a house on a site along hills with *gentle slopes*, which are not likely to slide.

Houses that are intended to resist strong winds during *Cyclones* need to be protected too by choosing appropriate site. Tall buildings sway significantly during strong cyclonic winds. In particular, the wind speeds are higher at *the peaks* or in *the upper halves* of hills, cliffs and mountain ridges; small houses or multi-storey buildings will be subjected to higher effects of cyclonic winds at such locations. Thus, it is best to avoid construction of houses at higher elevations of hills, cliffs and mountain ridges; ideally, houses should be constructed at the base of hills.

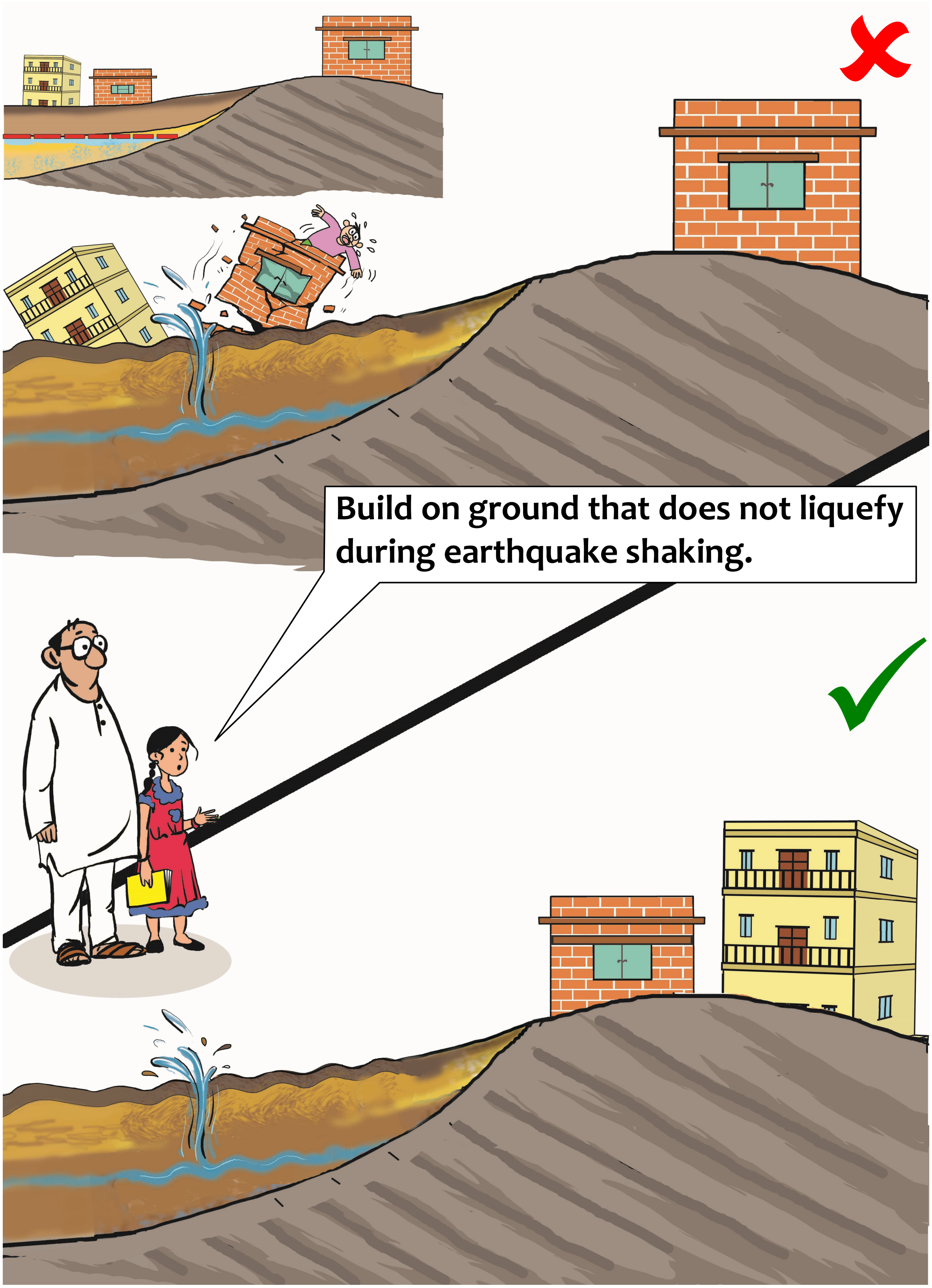


Build on Gentle Hill Slopes

Choose Suitable Soil Strata

Normally, soils are of three basic types, namely *sand*, *clay* and *silt*. Of these, if the water table is low, *sandy soil* is most suitable for construction. Generally, *clay soils* pose a problem of long term settlements, which damage buildings. And, *silty soils* have poor capacity to hold loads from buildings. Of these soils, soils that settle require more engineering effort to construct on, because settlement cannot be corrected during the process of design of the house; this requires improvement of the soil before design and construction. Further, *black cotton* soil and *murrum* soil are present commonly across India. Black cotton soil tends to expand and contract depending on the moisture content; this leads to *undesirable* differential settlement under the building. On the other hand, murrum soil is considered to be relatively better for construction, but it requires suitable amount of compaction before construction of houses.

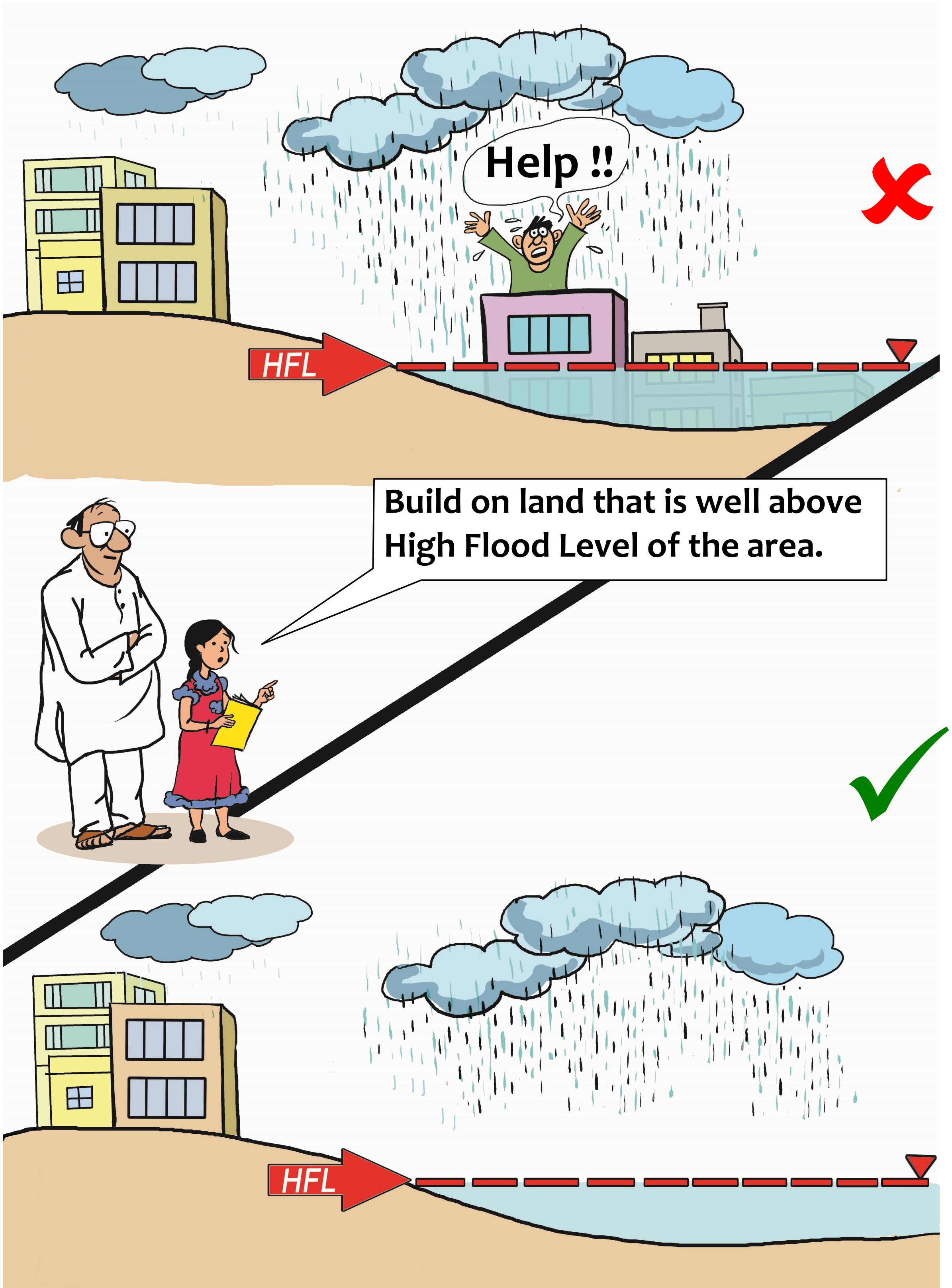
Sandy soils pose a peculiar problem. At a site with *loose granular cohesionless soil* (like *sand* of the same particle size), as the water level rises in the ground, the soil *looses its strength* to hold the houses built on it. The situation is *aggravated*, if such granular soil with high water table is subjected to *strong earthquake ground shaking* for a sufficiently large duration. In this situation, *solid* Earth becomes *liquid* Earth – this phenomenon is called *Soil Liquefaction*. Normal structures should not be built on such ground. Thus, it is best to choose sites that *do not liquefy* during strong earthquake shaking.



Choose Suitable Soil Strata

Don't Build in Low Lying Areas

Water flows from higher elevations to lower elevations. Thus, during rain or any other manmade events, water is likely to get collected in the *low lying areas*. Most locations have the *High Flood Level* (HFL) marked from the past natural events, like *annual floods* or *devastating cyclones*. Small single storey houses (built with normal functional design and with normal construction materials) cannot be designed to resist large pressures due to water. Also, if the level of water accumulated during floods is high, people living in such houses are likely to be *drowned*. Therefore, houses constructed in low lying areas are a threat to both *life* and *property*. On the other hand, multi-storey building structures can be designed to resist the large pressures of water, but the threat to life of people (by drowning) remains. Thus, it is best to identify such sites to construct houses, which are *well above* HFL in that area.



Don’t Build in Low Lying Areas

2

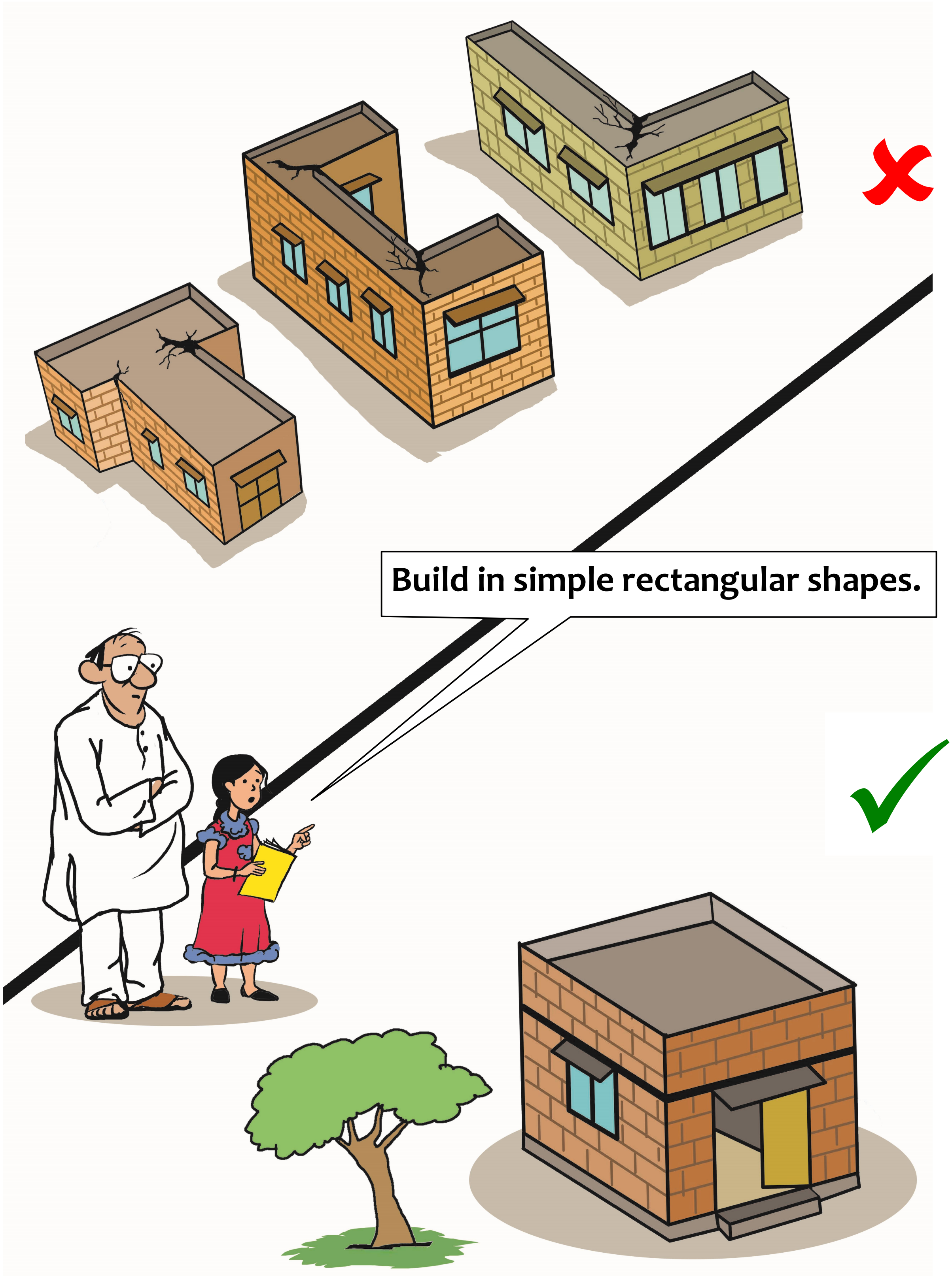
FORM

Appropriate Geometry and Sizing of a House

Shape of a Building in Plan

It is common practice to construct houses with *non-rectangular plan shapes*, like *T*, *L* and *C*. These houses are *functionally convenient*, but *structurally inefficient*. They require advanced engineering input to ensure that they do not get damaged during their life span, especially during *strong earthquake ground shaking*. In case of *large* engineered constructions, it may be possible to seek professional services of competent structural engineers to design them with such advanced engineering inputs. But, in *small houses*, this may not be affordable. Thus, it is best to choose building geometry that is composed of *simple rectangular shapes*.

Of the other commonly built plan shapes, circular and courtyard-type plan geometries are considered to be suitable for construction of small houses. In courtyard-type houses, ideally the opening should be in the center, and the area of the opening should be less than half the overall plan area of the house.

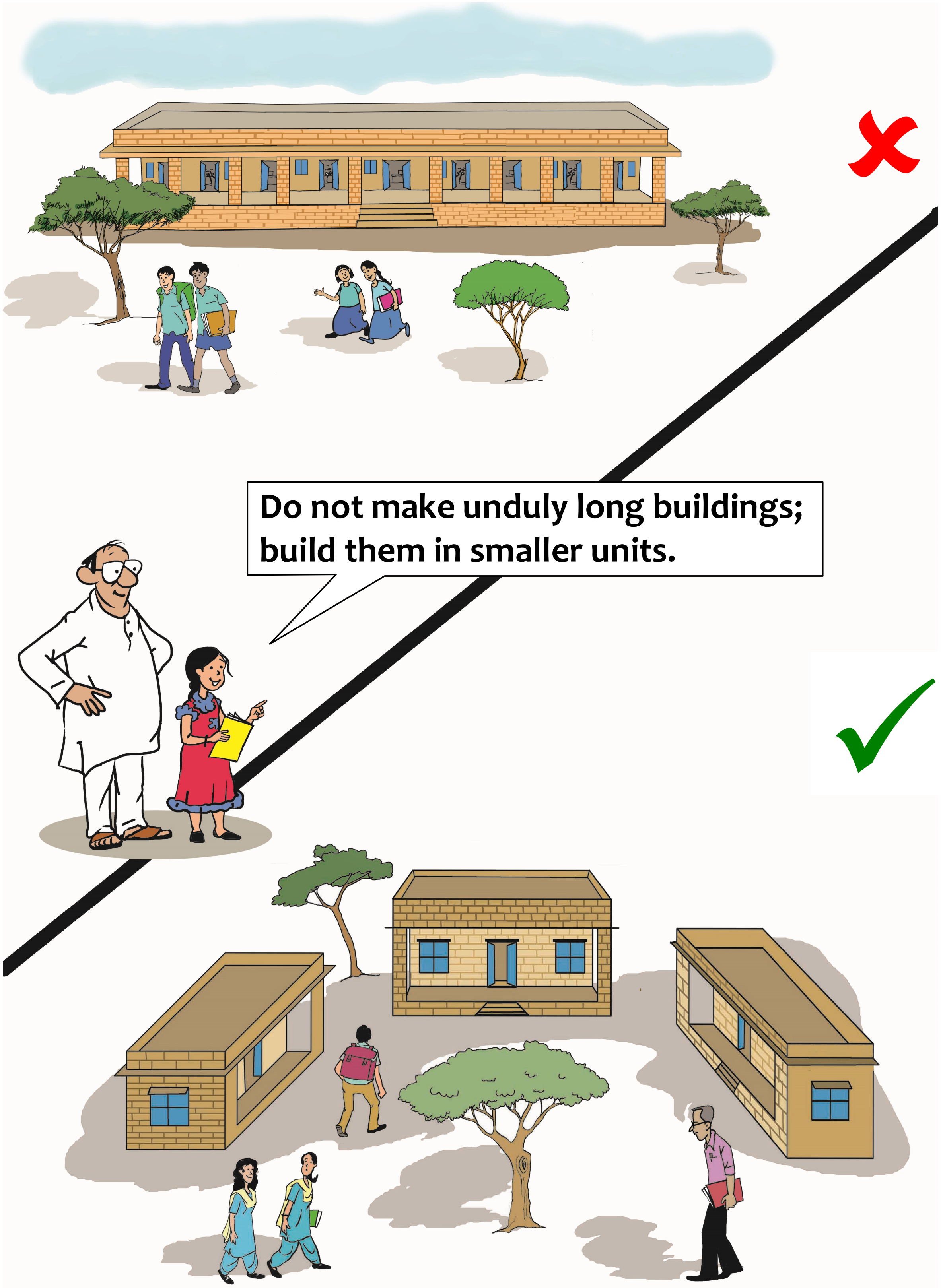


Shape of a Building in Plan

Length of a Building in Plan

Sometimes, long buildings are constructed, wherein the length is almost up to 8 to 10 times their width. Such buildings undergo different amounts of horizontal movement along the width of the building during strong earthquake ground shaking, and perform poorly. Thus, it is best to construct short length buildings, whose lengths are no more than *3 times their widths*. The more prudent way to construct is to build them in smaller units and well separated from each other.

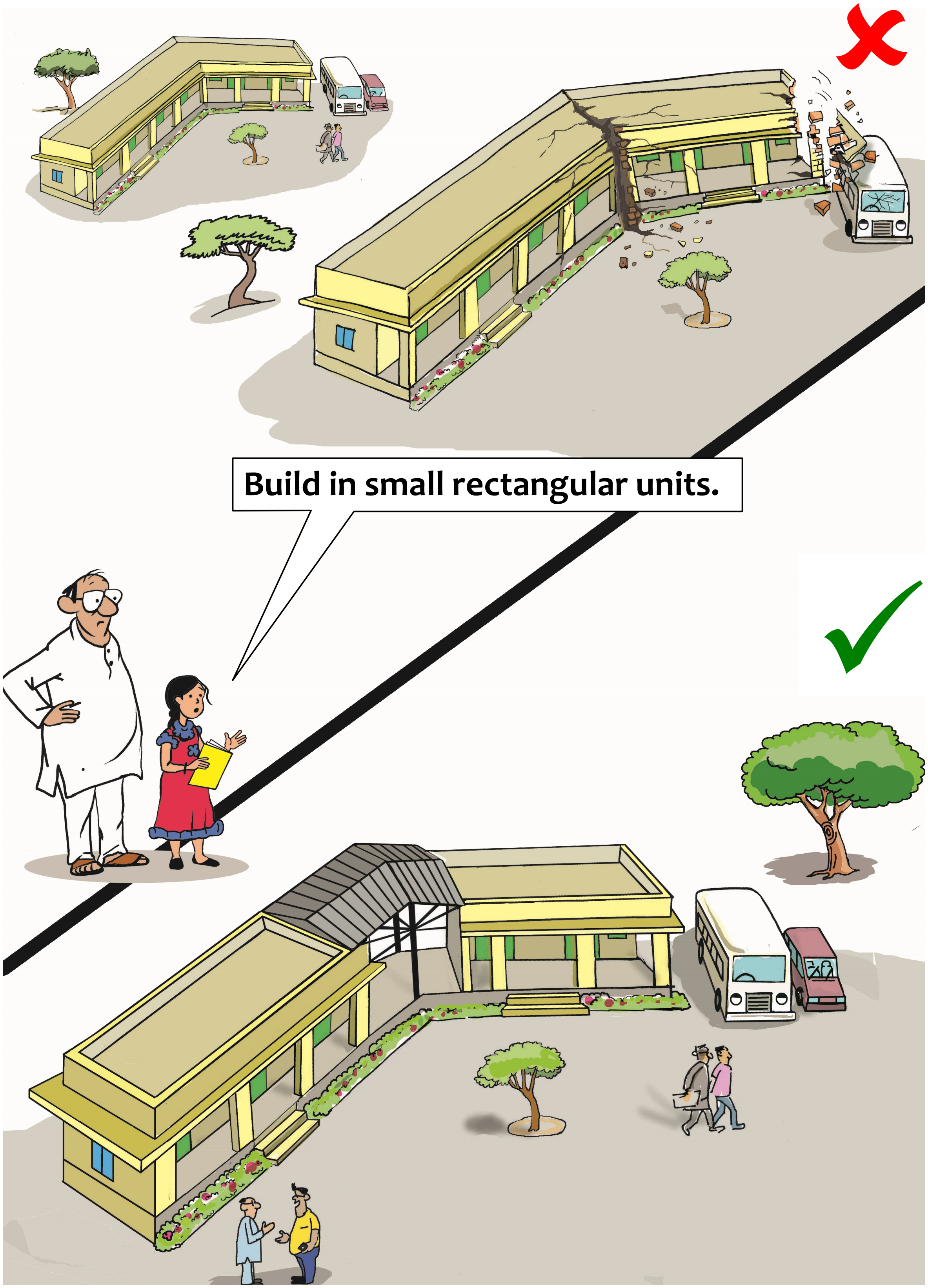
Row-housing is another form of house construction that is practiced in India. The plots of land are given to individual persons, and the individuals construct houses over time. They join them nominally at the floor levels. Thus, these buildings constructed incrementally over time are composed of many small units. Such buildings perform poorly.



Length of a Building in Plan

Buildings Bent in Plan

A long building may be resting on ground whose soil is not necessarily uniform. So, the building may *settle vertically by different amounts* at different points along its length. Even if the soil is good and it does not cause any differential downward settlement along the length of the building, a long building will be shaken horizontally *by different amounts* along its length during strong earthquake shaking. This can cause extensive damage to the building, and may even cause collapse of the building. The problem is aggravated, when the building is *bent in plan*. Thus, it is best to make the building in smaller *rectangular units* with a flexible joint at the location of the bend. The flexibility at the joint can be achieved by using a light roofing system.

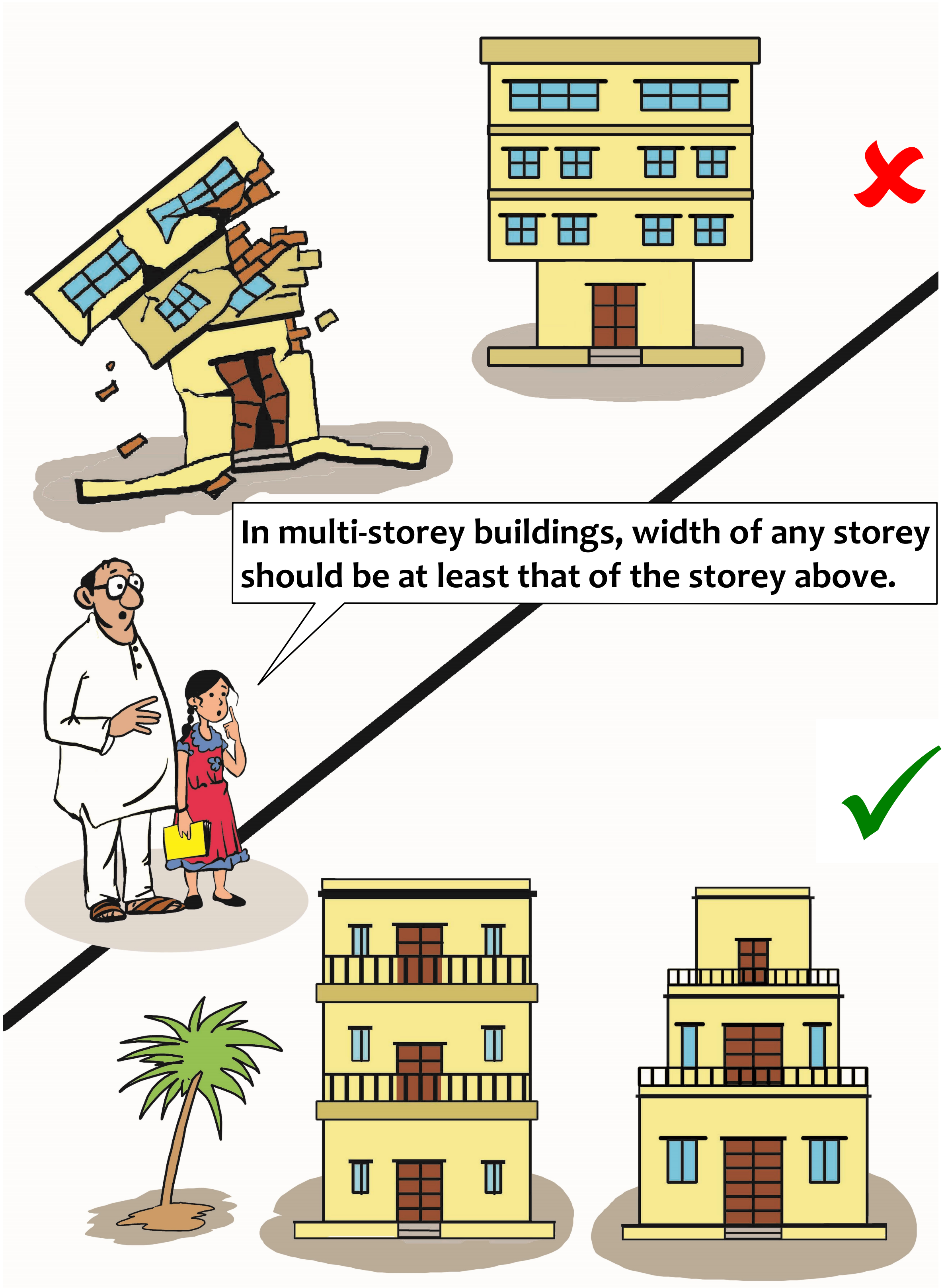


Buildings Bent in Plan

Shape of a Building in Elevation

Buildings *having larger width in upper storeys* than in the lower storeys are observed commonly in the country. Also, some bye-laws allow horizontal overhangs in buildings. Such features (namely wider upper storeys and horizontal overhangs in any storey) are undesirable, because such buildings with such features perform *poorly*, especially during *strong earthquake ground shaking*. Thus, it is best to choose the geometry of the multi-storey building such that:

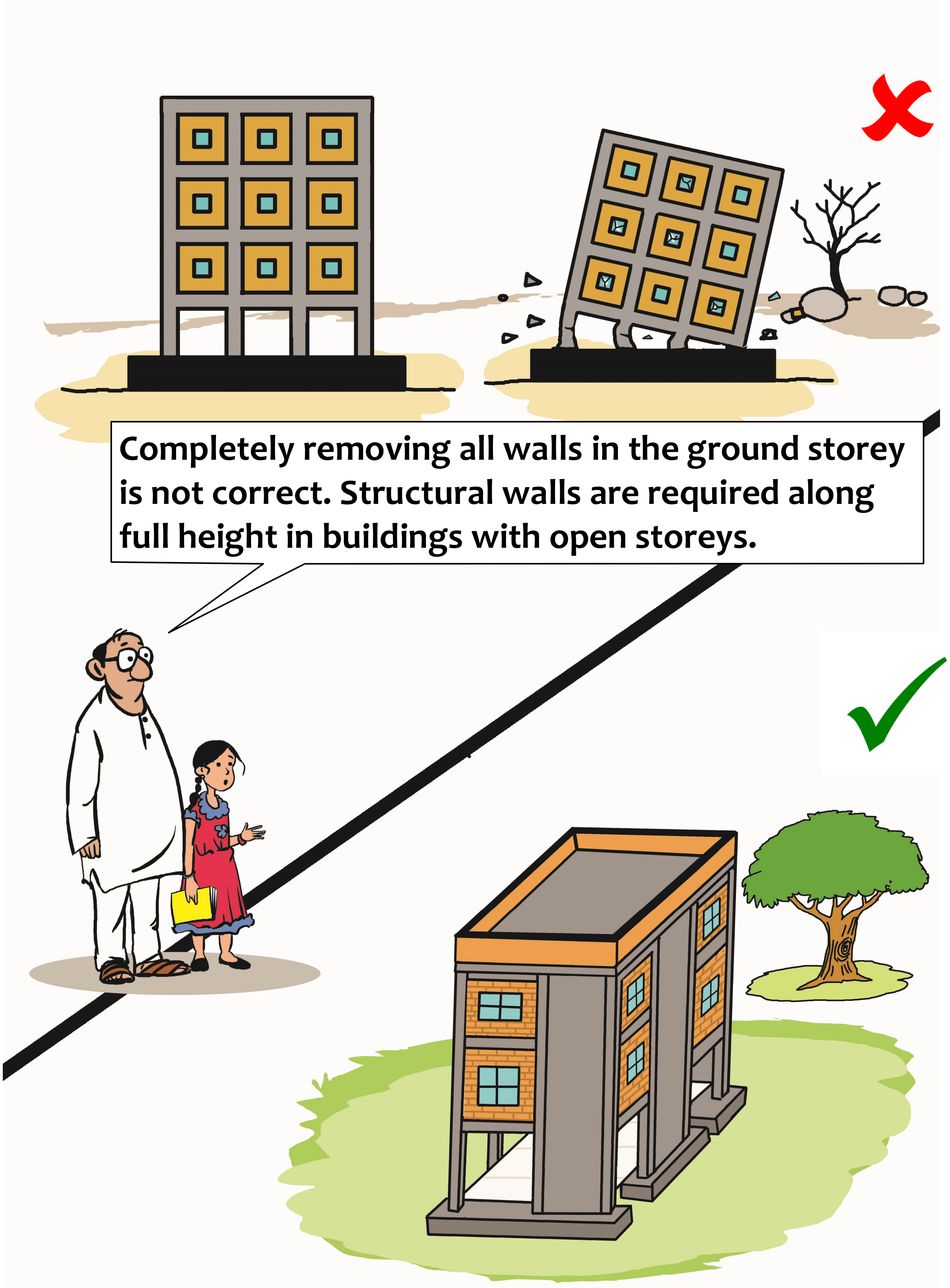
(1) Building width is the same along the height; or
(2) Building width is *more in lower storey* than in the *adjoining upper storey*.



Shape of a Building in Elevation

Buildings with Open Ground Storey

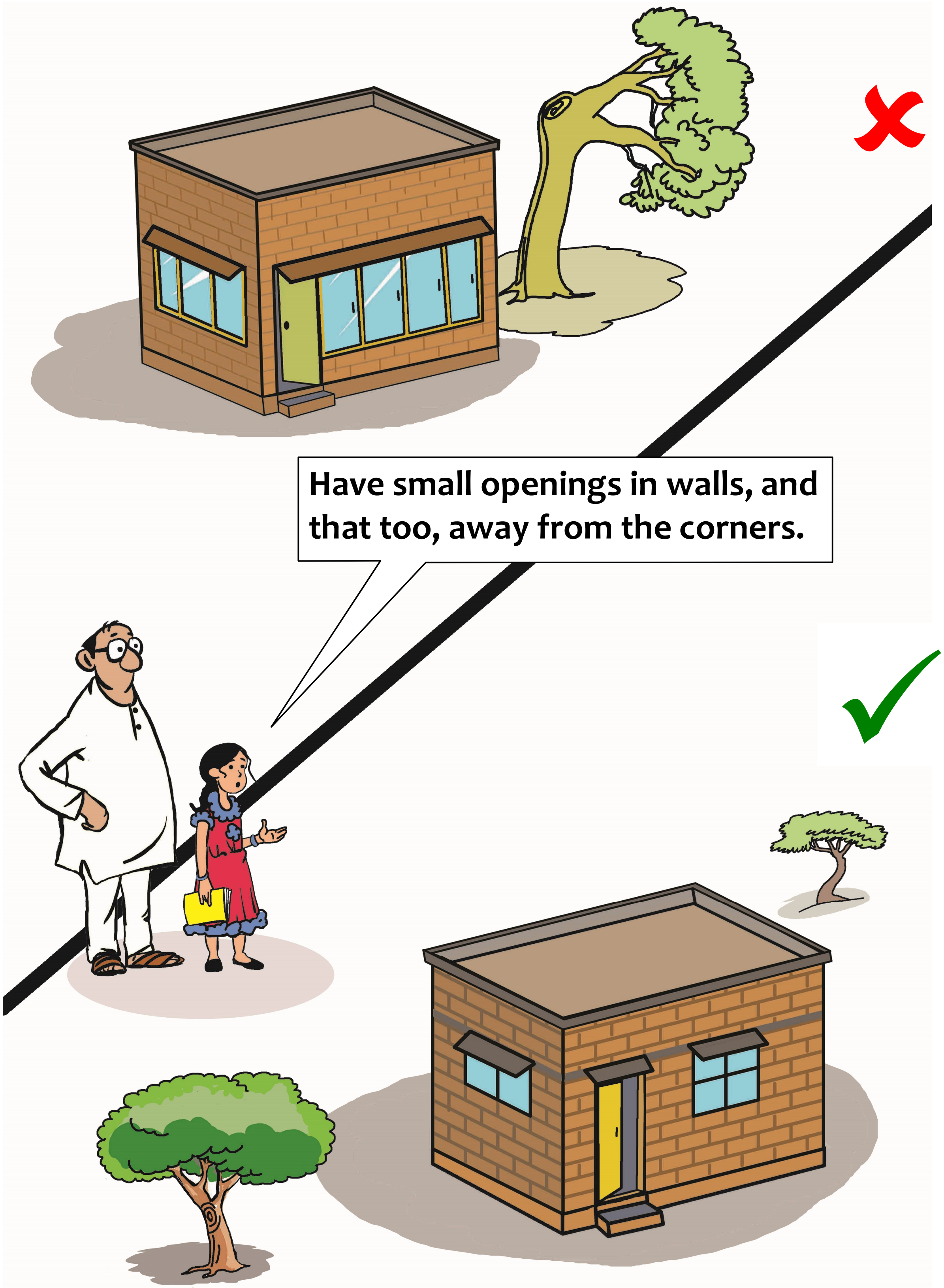
A special class of residential and low-rise commercial buildings is popular across the country. Most of these buildings are made of RC columns, beams, slabs, and *unreinforced masonry* (*URM*) infill walls made of burnt clay bricks, cement concrete blocks or fly-ash units. The *unique* distinguishing feature of these buildings is that the ground storey is used for parking of cars and motorised vehicles. No walls are built in *this ground storey*. Such buildings have performed poorly during past earthquakes in the country, owing to the failure of the RC columns in the open storey. Ideally, these open storeys should be stiffer and stronger than currently practiced. Therefore, it is best to ensure that such buildings are designed and constructed with *RC Structural Walls along the full height* of the buildings.



Open Ground Storey Buildings

Openings in Walls

Buildings with *large sized openings* to accommodate windows and doors have many problems. They allow large amount of heat to *enter* the building, which is not desirable in a tropical country like India. In hilly areas also that are likely to sustain snow, such large openings allow excessive *drop* in temperature inside the house, because large window openings allow more cold to come in. Further, such houses with large openings perform poorly during earthquakes. Under *strong earthquake ground shaking*, the house swings horizontally by large amounts, if it has large openings. Such large movements are detrimental to both the house *structure* and its *contents*. In masonry houses, the problem is aggravated, when the openings *start at* or are *close to the wall corners*; this weakens the connection between the walls and can *lead to collapse of the house* during strong earthquake ground shaking. Thus, it is best to ensure that houses have *small openings* in walls, and that too, well *away from wall corners*.



Openings in Walls

3

MATERIALS

Quality Materials for Constructing a House

Quality of Bricks

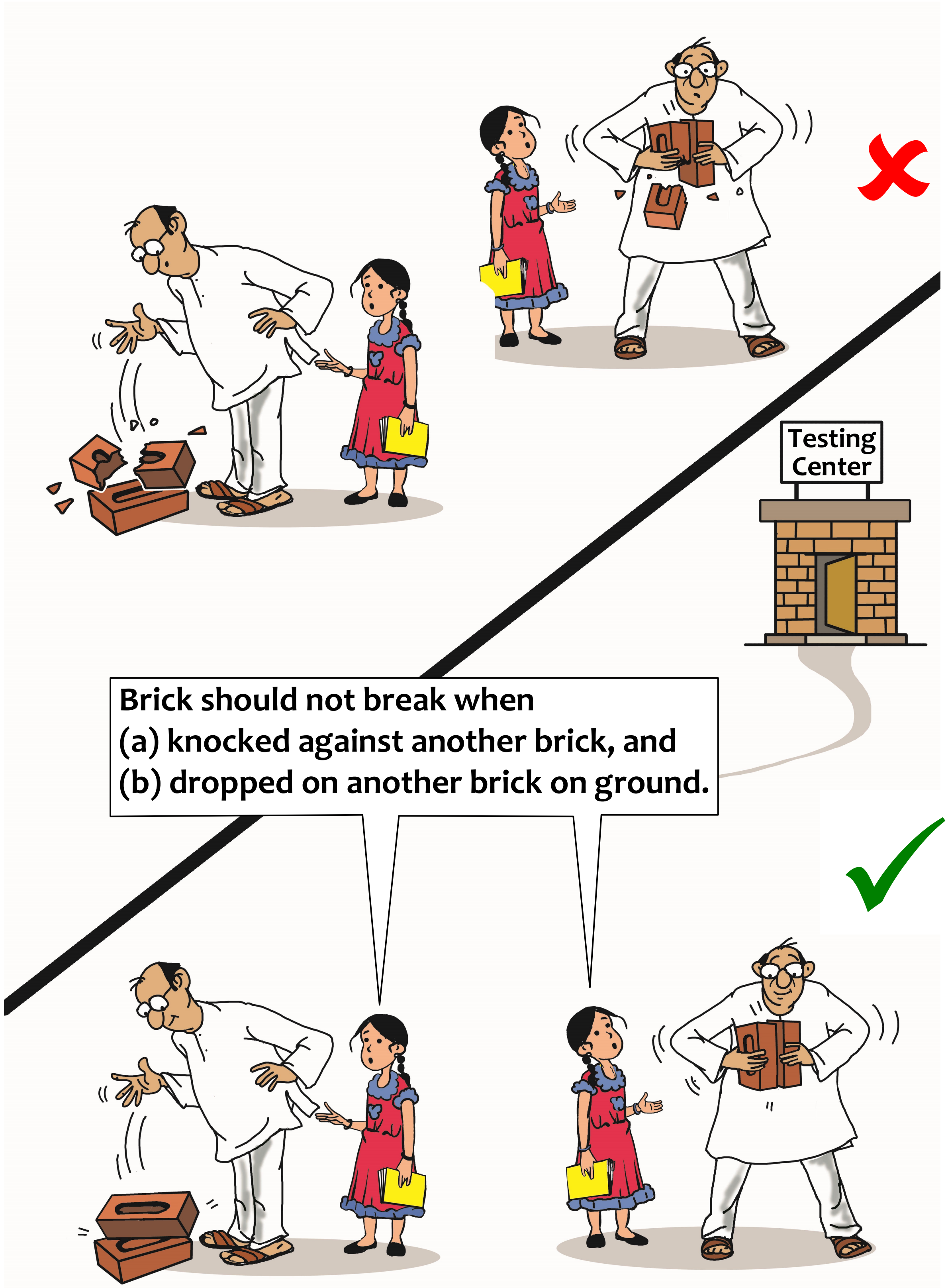
Clay bricks are popular in India. As per 2011 Census of India, in about 60% of houses, the walls are made of *burnt clay bricks*, and in about 21% of *unburnt clay* or *mud*. The bricks are made of top soil available in the near neighbourhood. Their quality differs across the country, owing to type of soil, workmanship, and method of manufacture. Simple ways of identifying their quality are:

(1) Drop a brick from shoulder height on to another that is already placed on ground – *neither of the bricks should break*.
(2) Knock two bricks with a pair of hands – *neither of the bricks should break*, and *they should give a nice ringing sound*.

Even if the bricks are made of fly-ash, cement concrete or any other material, the above two field tests are good ways of identifying that they are worthy of being considered in the construction of houses.

Once they pass these tests:

(a) In the construction of multi-storey buildings, the bricks to be used in the construction of a house should be sent to a *Testing Center* for ascertaining their engineering properties, and thereby *confirming* their suitability for use in the construction of houses; and
(b) In the construction of individual houses, when testing is not possible, competent engineer in the neighbourhood should be consulted for checking if the quality of *bricks* is acceptable as per national standards.



Quality of Bricks

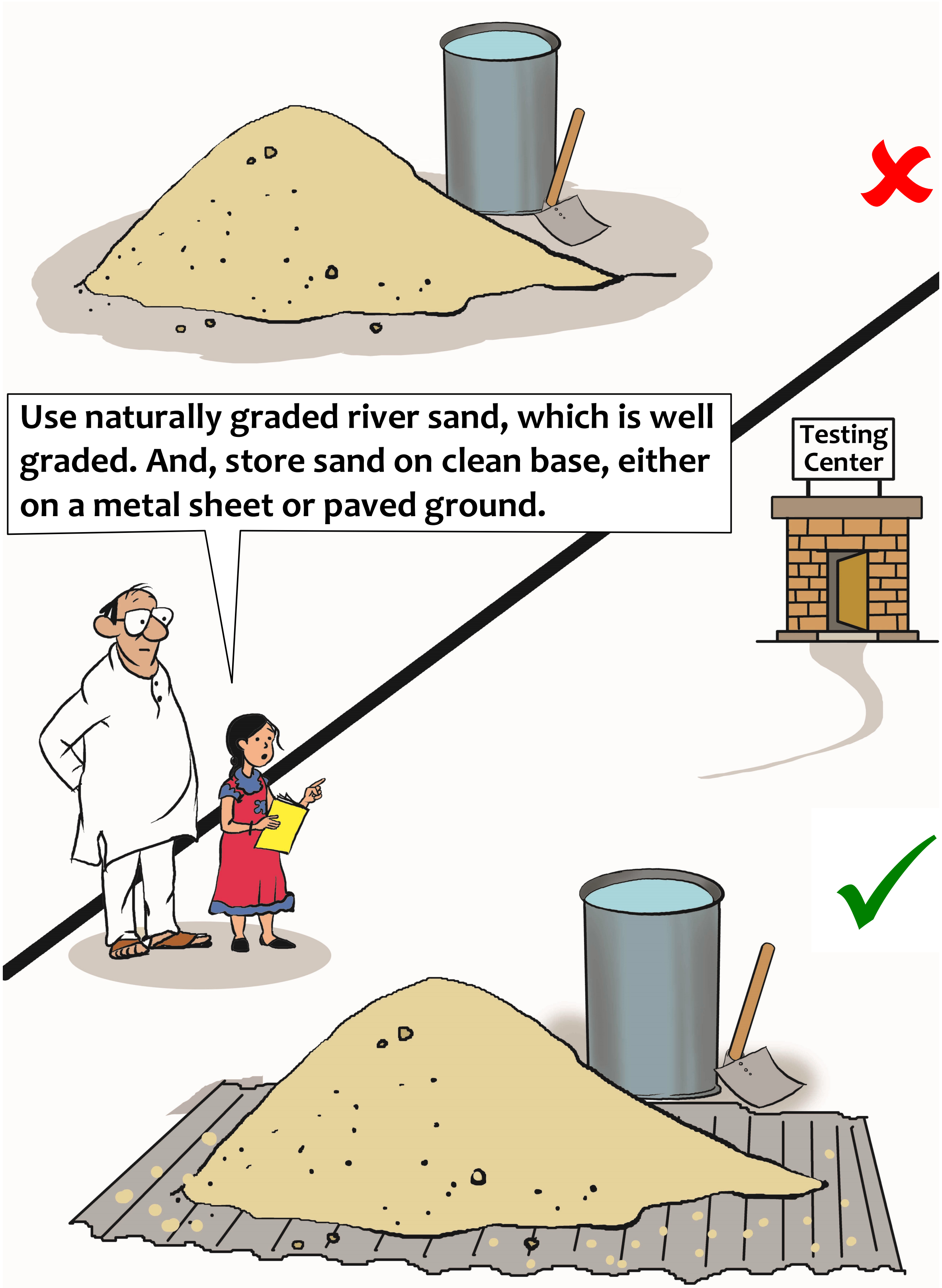
Quality and Storage of Sand

Sand is used in the construction of houses in India – in *masonry work* related to foundation and walls, and in *RC work* in foundations, columns, floor beams, and floor & roof slabs. *River sand* is recommended in the Indian Standards for use in masonry and concrete works. Sometimes, natural pit sands are equally good. But, in recent times, sand is being *manufactured from stone* too. These manufactured sands vary in their properties across the country, and should *not* be used without testing. Simple checks for good quality sand are:

(1) It should not contain any *soil* or *mica* in it, and have a uniform colour.
(2) It should be *well graded*, and not have grains of only *one size*.

Sand should be stored on a *clean base* (either on a metal sheet, or on paved ground).

The sand to be used in the construction of a house, should be sent to a *Testing Center* for ascertaining its engineering properties, and thereby *confirming* its suitability for use in the construction of houses. When testing is not possible, competent engineer in the neighbourhood should be consulted for ensuring that the quality of *sand* is acceptable as per national standards.



Quality and Storage of Sand

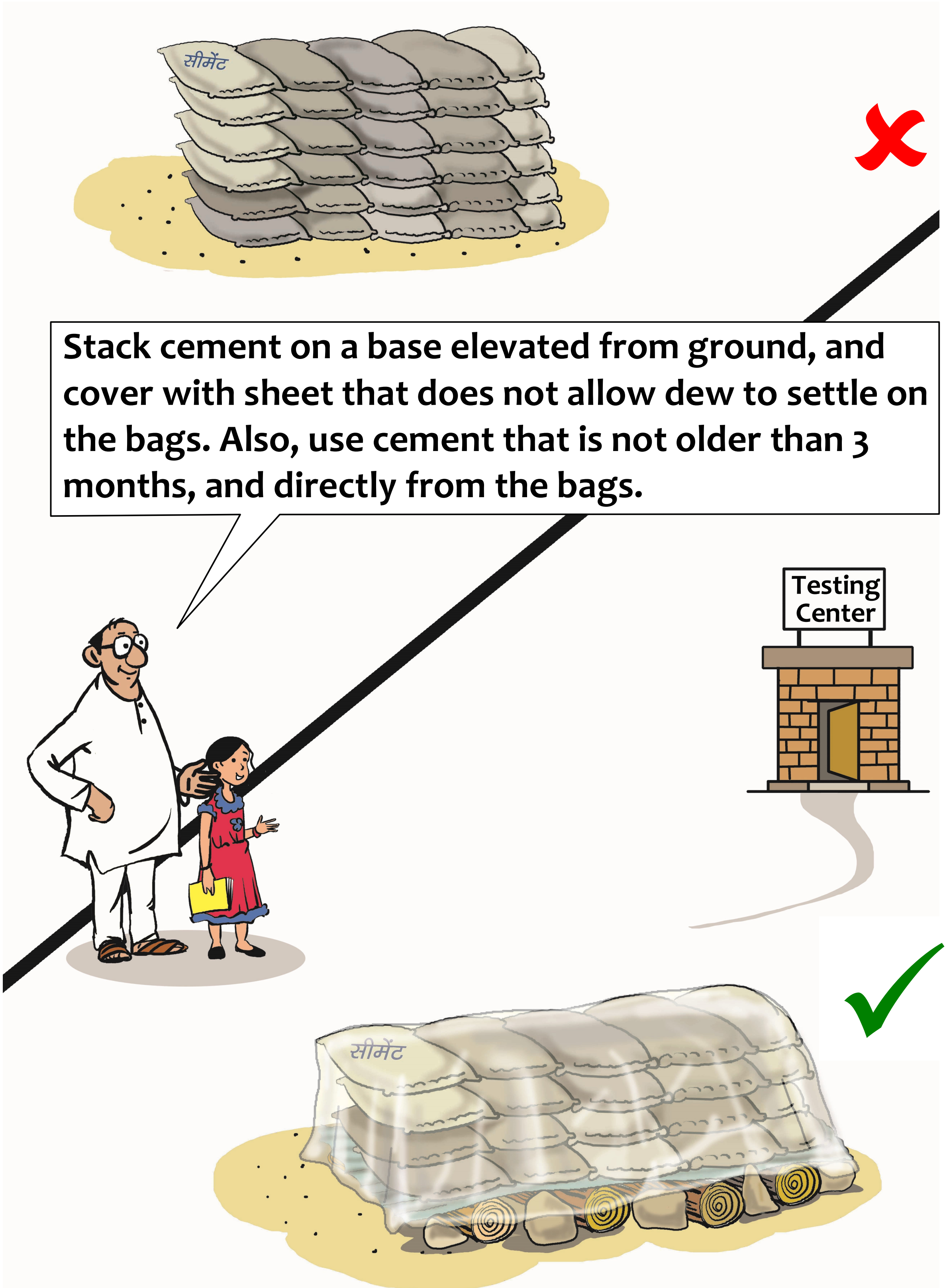
Quality and Storage of Cement

Cement is an engineered material, which is manufactured in cement plants across India. They are made of natural raw materials, like *limestone* and *silica*. *Portland Pozzolona Cement* is recommended in the Indian Standards for use in masonry and concrete works. But, sometimes other ingredients are added to give it special properties, like *delayed setting time* or *improved flowability*. This engineered material should be stored properly until use. Simple rules in this regard are:

(1) It should be kept indoors, preferably, and covered with an impervious sheet to avoid any overnight dew or moisture from entering the cement.
(2) It should be stacked with no more than 5 bags atop each other.
(3) It should be used within three months of manufacture.

Because there are variations in the methods of transportation and storage, the properties of cement vary at sites across the country. Thus, only cement tested just before construction should be used.

The cement to be used in the construction of a house should be sent to a *Testing Center* for ascertaining its engineering properties, and thereby *confirming* its suitability for use in the construction of houses. When testing is not possible, check ISI certification mark on the cement bags for ensuring that the quality of *cement* is acceptable as per national standards.

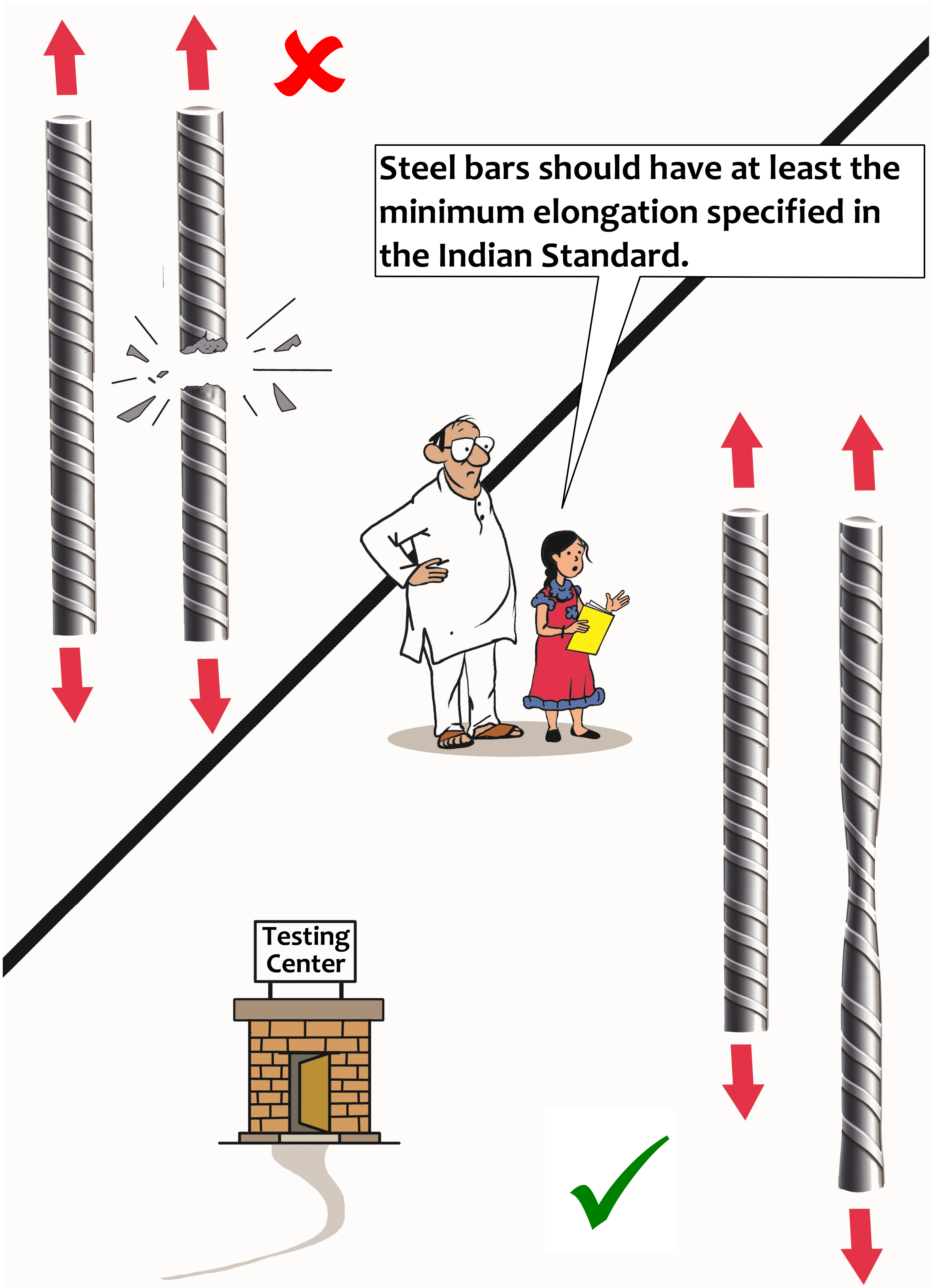


Quality and Storage of Cement

Quality of Reinforcing Steel Bars

Reinforcing Steel, used in RC as *bars*, is another engineered material, which is manufactured in steel plants across India. The bars are made of natural raw materials, like *iron ore*. *Thermo-Mechanically Treated (TMT) bars* are recommended in the Indian Standards for use in RC works. There are a number of steel plants that *recycle scrap steel* as raw material to make reinforcing steel bars; such steels have large variations in their engineering properties, and should not be used without testing. The steel bars should be able to elongate when pulled at their ends, at least by about 10.5% to 25%, as specified in the Indian Standard.

Therefore, the reinforcing steel bars to be used in the construction of a house should be sent to a *Testing Center* for ascertaining their engineering properties, and thereby *confirming* their suitability for use in the construction of houses. When testing is not possible, check ISI certification mark on the *reinforcing steel bars* for ensuring that their quality is acceptable as per national standards.



Quality of Reinforcing Steel Bars

4

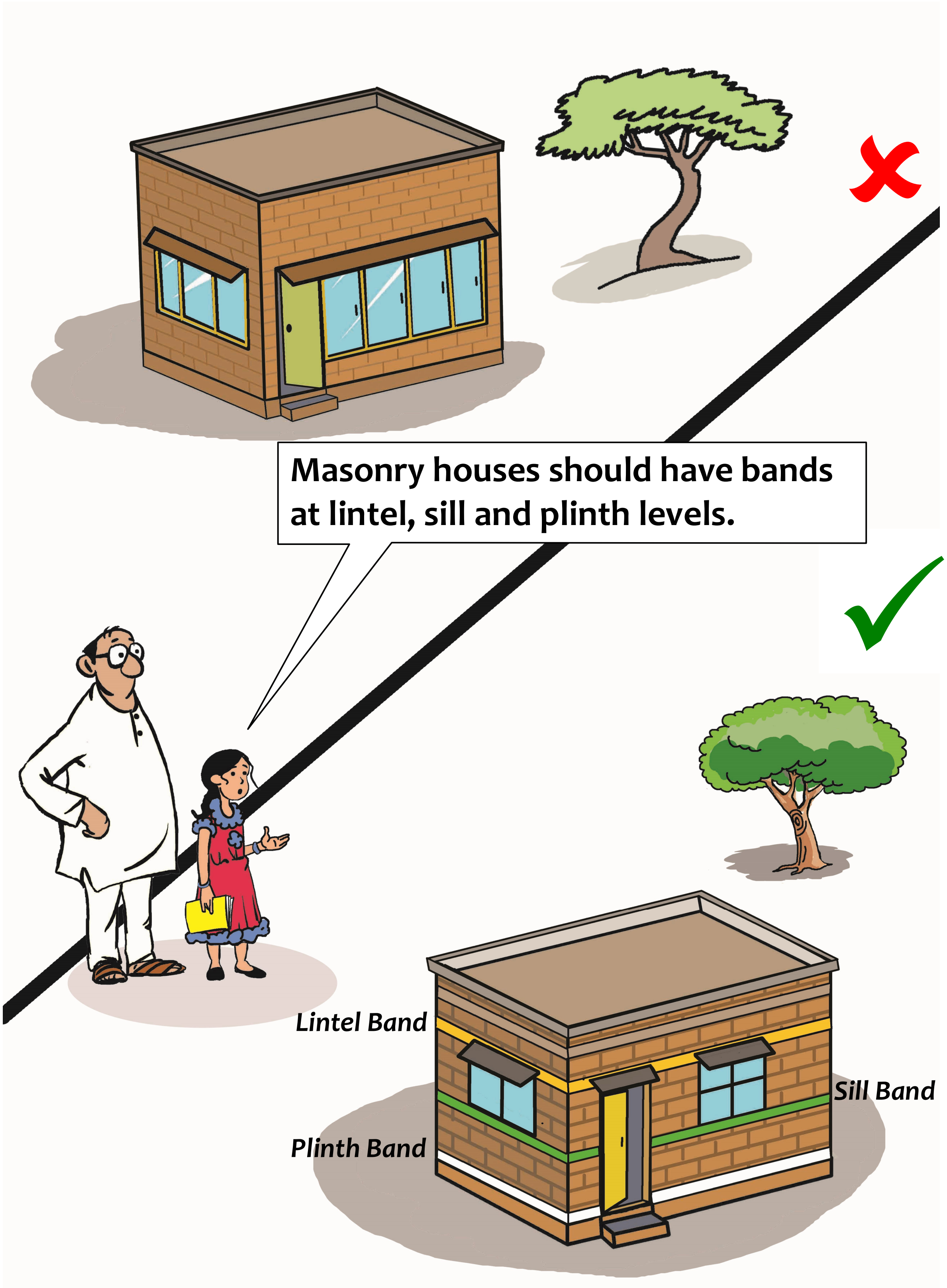
TECHNICAL DETAILS

Special Engineering Details of a House

Tying Masonry Walls with Bands

Horizontal bands are important earthquake-resistant features in brick and stone masonry houses. Bands hold all walls of a masonry house as a single unit by tying the walls together. Three types of bands should be present in a typical masonry house with flat roof, namely *lintel band*, *sill band* and *plinth band*. The *Lintel Band* is the most important of all, and needs to be provided in all buildings. The *Sill Band* is desirable for improving the behaviour of masonry houses during strong earthquake ground shaking, especially when the storey height is large. The *Plinth Band* is used primarily when there is concern about uneven settlement of the soil beneath. In buildings with flat RC slabs as roof, no band is required at the roof because the roof slab itself plays the role of a band.

In RC buildings, no bands are required, though lintels are provided routinely. And, when individual footings are used as foundations under the columns, the columns should be tied together with *tie beams*.

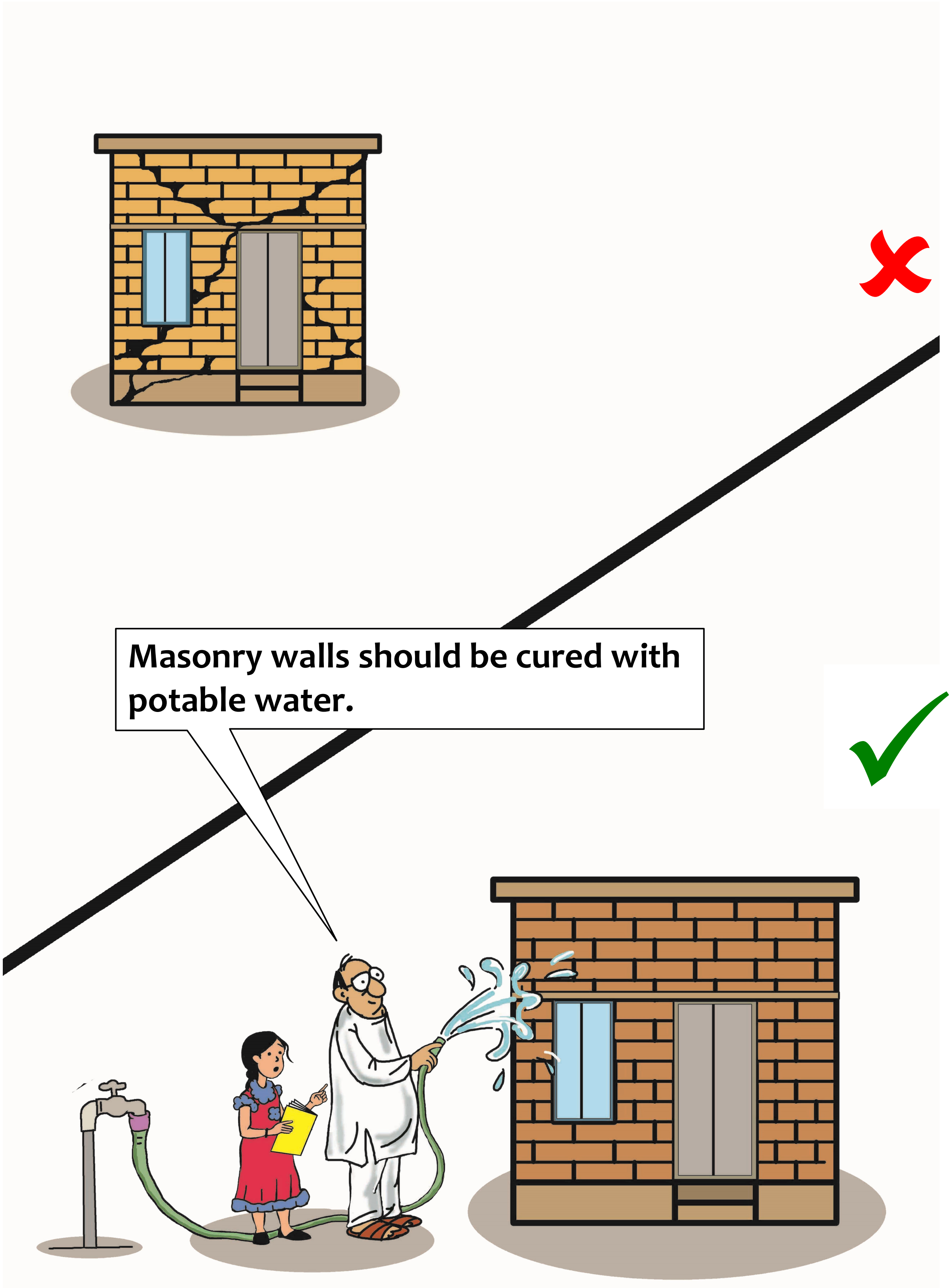


Tying Masonry Walls with Bands

Curing Masonry Walls

In India, commonly, masonry walls are made of *masonry units* (like *clay bricks* or *stone*) and *cement mortar*. These two materials have different engineering properties. Hence, extra care is required to make them work together. One critical aspect is that the cement mortar should posses at least a minimum *strength* to be able to bond the masonry units together. The process that ensures that the mortar attains its strength is *curing*. After the initial set of the mortar, as the mortar hardens, it releases heat. This heat must be removed quickly, so that the mortar does not become *weak* and *crumble* due to this heat. The way this is achieved is by keeping the mortar moist, by squirting water on the walls from the second day of the construction. *Potable water* should be used for this purpose. Sometimes, *jute bags* are tied to the walls with ropes, and kept moist by squirting water periodically. This exercise should be continued for at least 7 days.

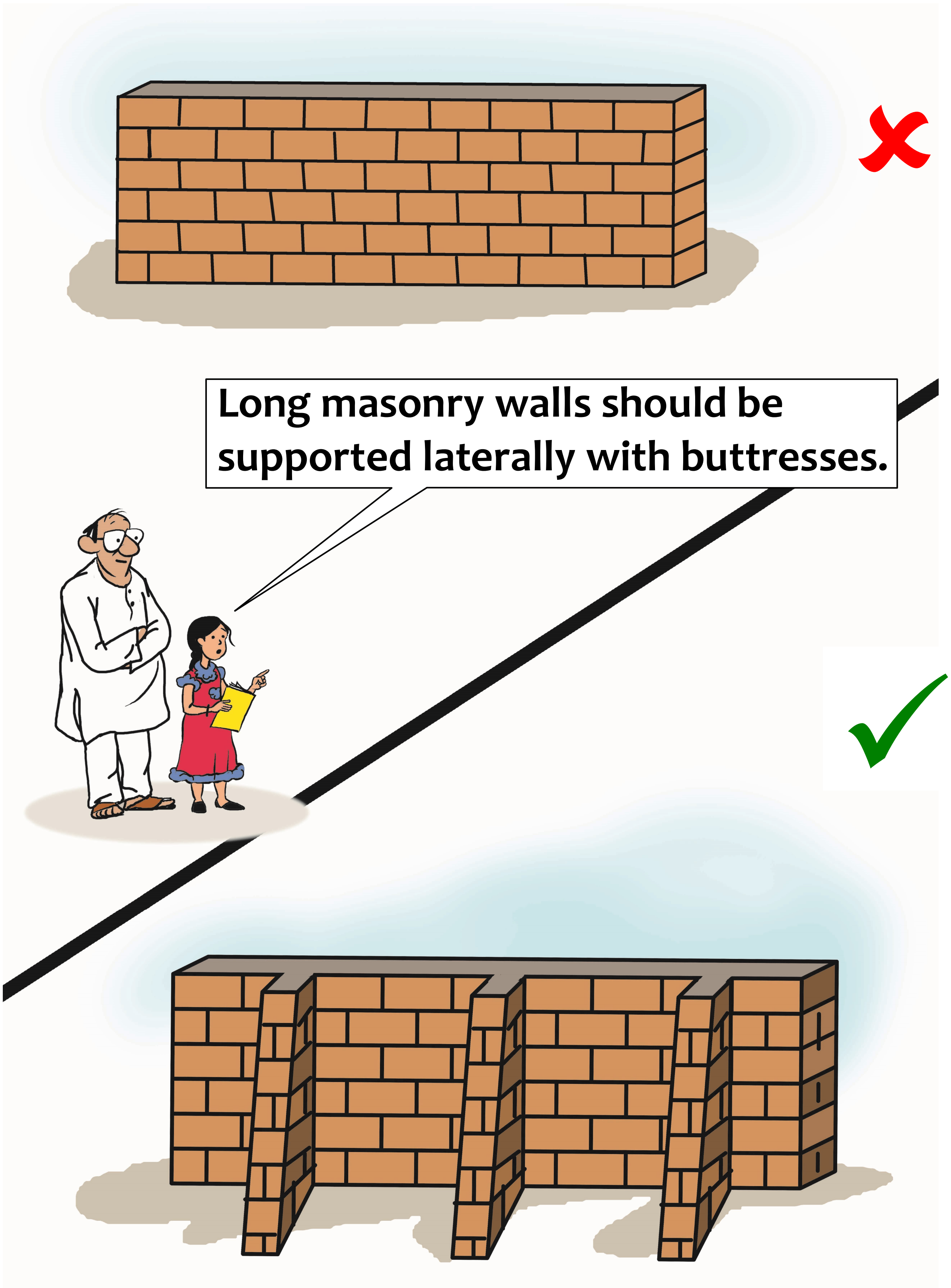
Even elements of *RC* buildings, namely *foundations*, *columns* and *beams*, should be *cured* for at least 14 days. For curing *slabs*, small bunds (of about 2 inches height) are made with *soil* or weak cement mortar, and water is poured to make small ponds on top of the slabs. Ponding is not possible in *vertical members*, like *columns*; jute bags are tied to the vertical surfaces and water is squirted periodically to keep them moist.



Curing Masonry Walls

Protecting Long Walls

Masonry walls are said to be *long*, if their lengths are larger than specified value between supports. The minimum thickness of masonry walls should be *230mm*, when they carry the roof or floors. Also, typically, the length between the vertical supports should not be more than *27 times* the wall thickness. If the length exceeds this value, the wall should be supported laterally with vertical supports made of masonry of *one brick thick* (230mm) and projecting perpendicular to the wall, by at least *1/5th* the height of the wall. These supports should be integrated with the main wall, by *proper toothing* following the masonry courses.

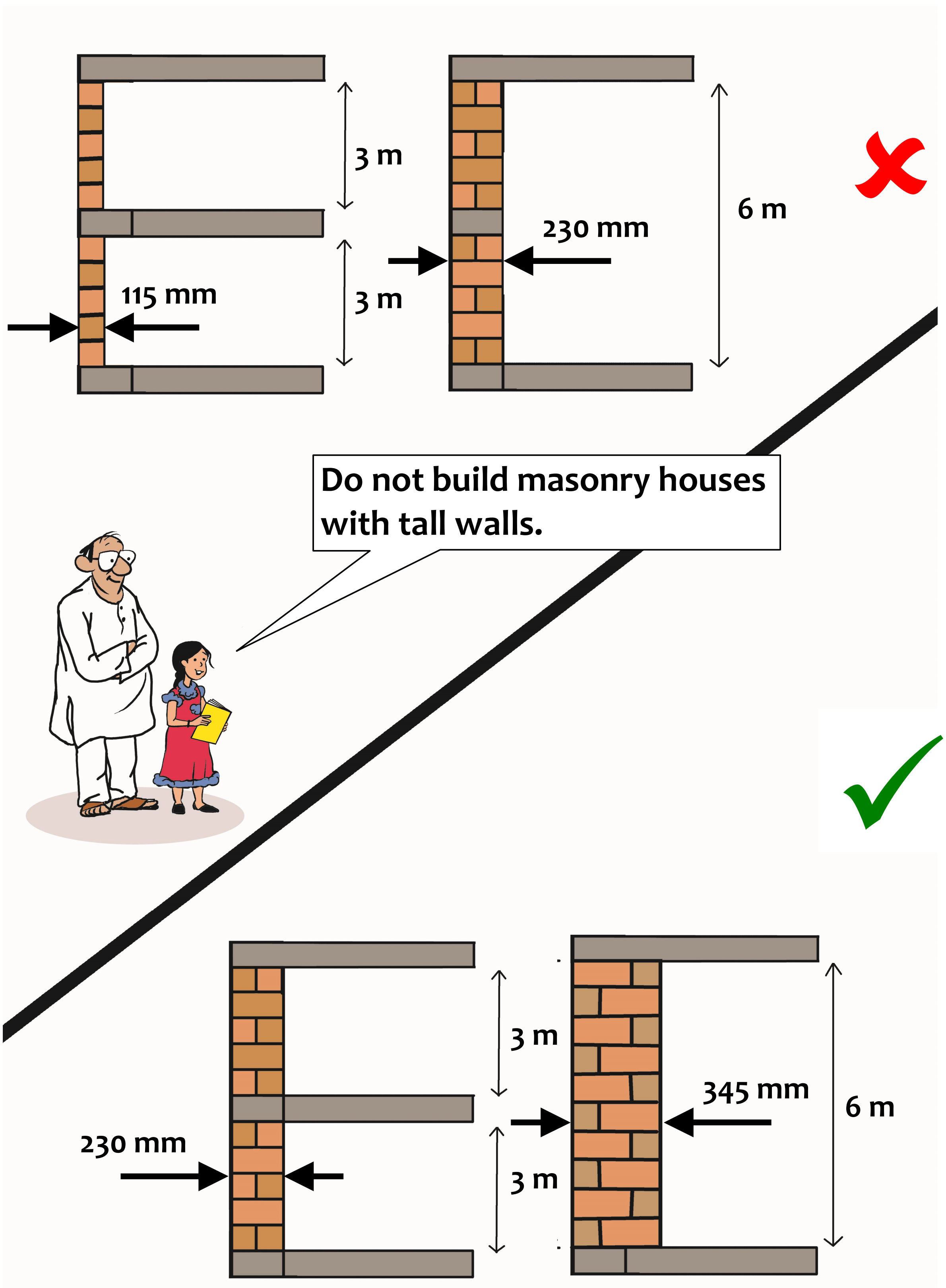


Protecting Long Walls

Protecting Tall Walls

Masonry walls that carry roof or floors are important elements. They should not be *too tall*, *i.e.,* their height should not be larger than a specified value. The minimum thickness of masonry walls should be *230mm*. Typically, the height should not be more than about *14 times the wall thickness*. If the height exceeds this value, the wall should be provided with *horizontal bands* made of reinforced concrete, running throughout the perimeter of the house. The height between the bands should be less than *14 times the wall thickness*.

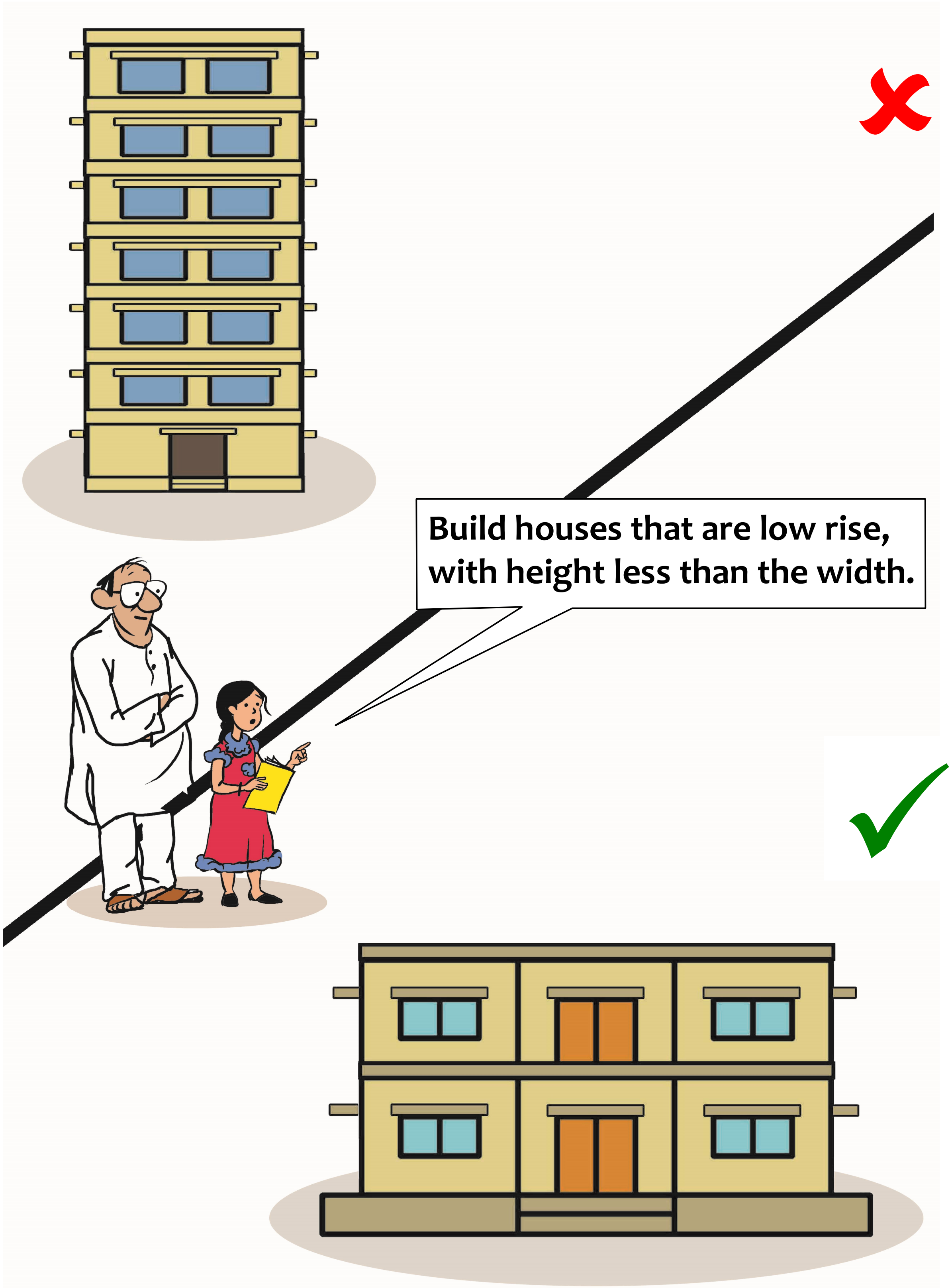
As the height of the wall increases, its thickness should increase too. Thus, masonry walls can be made thicker to construct taller buildings. But, increasing the thickness of the walls results in increase in the mass of the building, which is not desirable under earthquake ground shaking. Typically, one storey houses are built with about *3m* storey height; experiences in past earthquakes have shown that full brick walls of *230mm* thickness are required, and half brick thick walls of *115mm* thickness are insufficient. Sometimes, houses have one part taller than the others. And, if the height of the wall between floors (or floor and roof) is about *3m-6m*, then at least 1½ brick thick walls of 345mm thickness are required. When thicker walls are required in the upper storeys owing to larger walls heights, the thickness of the wall in the lower storey should be at least equal to the thickness of wall in the upper storey.



Protecting Tall Walls

Deciding Height of a House

Conceptually, engineers can design and construct buildings of any height. With *engineered* materials, like *high strength* concrete and steel, it is possible to build *tall* buildings. But, this needs competence in structural engineering, especially related to tall structures. On the other hand, with *masonry*, there is a limit to the maximum height of the unreinforced masonry buildings that can be built. This is attributed to the *limited strength* of masonry. Normally, masonry houses up to *2* storeys of about *3m* storey height can be built with one brick thick walls, but such houses should have RC *bands*. As the height of the house increases, extra care is required. Thicker walls and some steel reinforcement are required in them; such buildings are called *reinforced masonry buildings*. But, using thick walls also results in *larger mass*, and thereby *increasing* the earthquake effects on them. While it is possible to build taller masonry buildings, it is best to limit the heights of masonry buildings to about three storeys in earthquake prone areas.

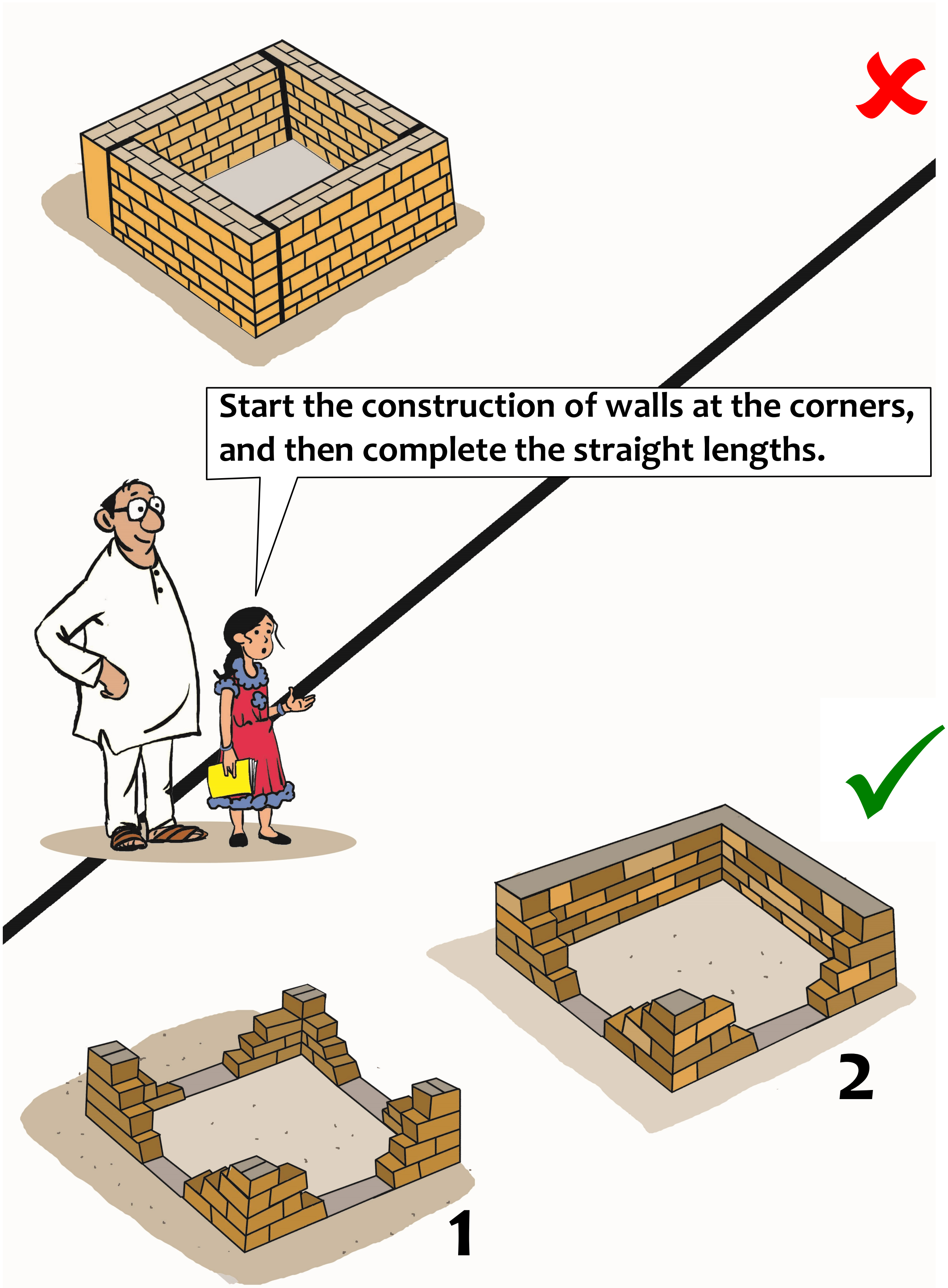


Deciding Height of a House

Constructing Masonry Walls

The most critical aspect of construction of a masonry house is the *tying together of the walls*. For ensuring this,

(1) They should be constructed together from the foundation level to the roof level; and
(2) The *sequence* of construction of the masonry is *first* construct the *corners* or *junctions of walls* as a single unit following the rules of masonry courses, and *then* complete the masonry *in the straight lengths* starting at the corners or junctions in keeping with the masonry bonds.



Constructing Masonry Walls

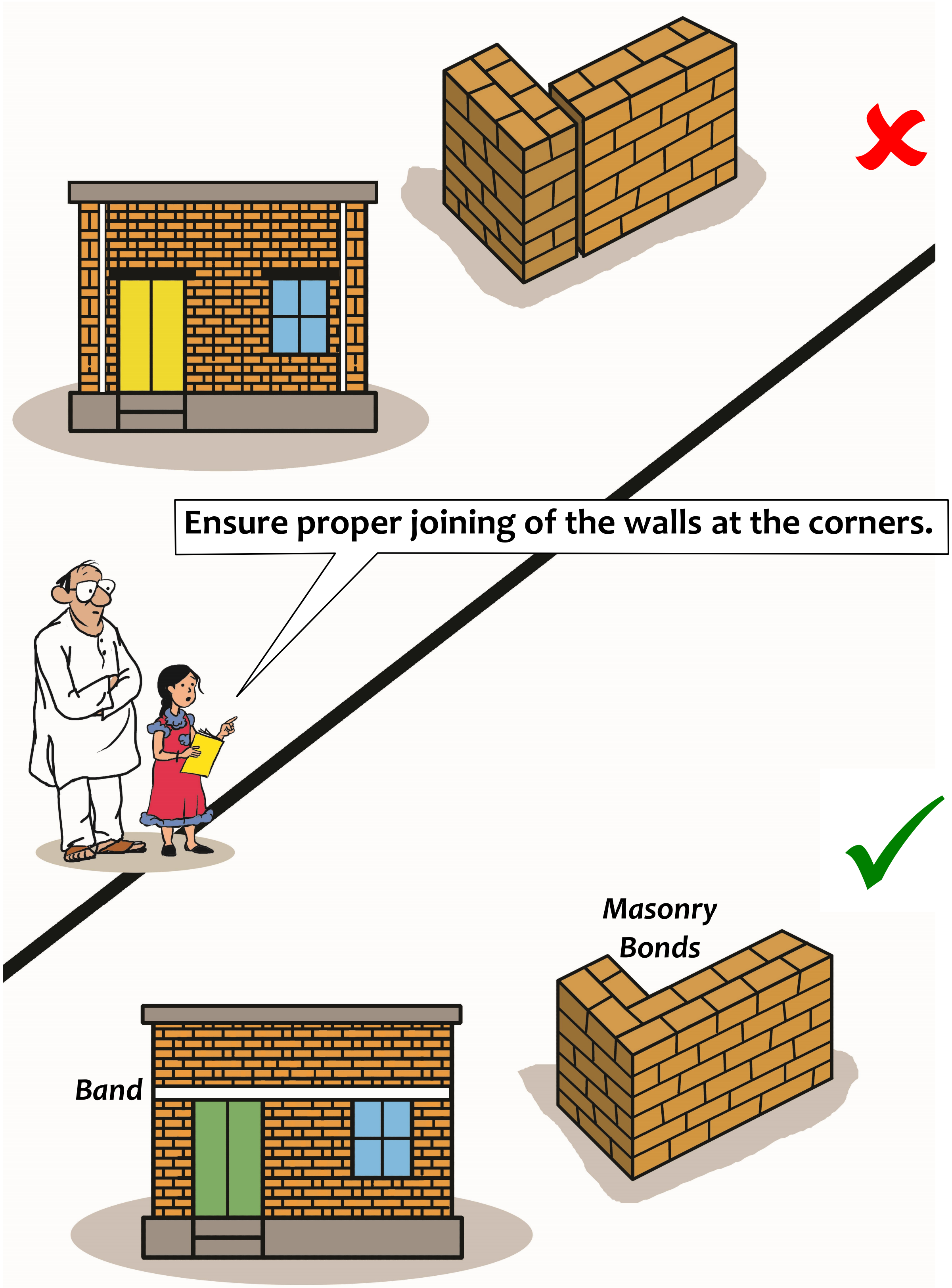
Joining Masonry Walls

Masonry walls should be joined together both *locally* and *globally* at the corners. Joining the walls *locally* requires:

(1) Ensuring masonry bonds in the courses, especially at the corners and junction of walls, and

(2) Starting the construction of walls at the corners and then completing the straight lengths.

And, joining the walls *globally* requires the use of *bands* (made of *RC with sufficient steel bars)*, running along the perimeter of the walls in the entire house.

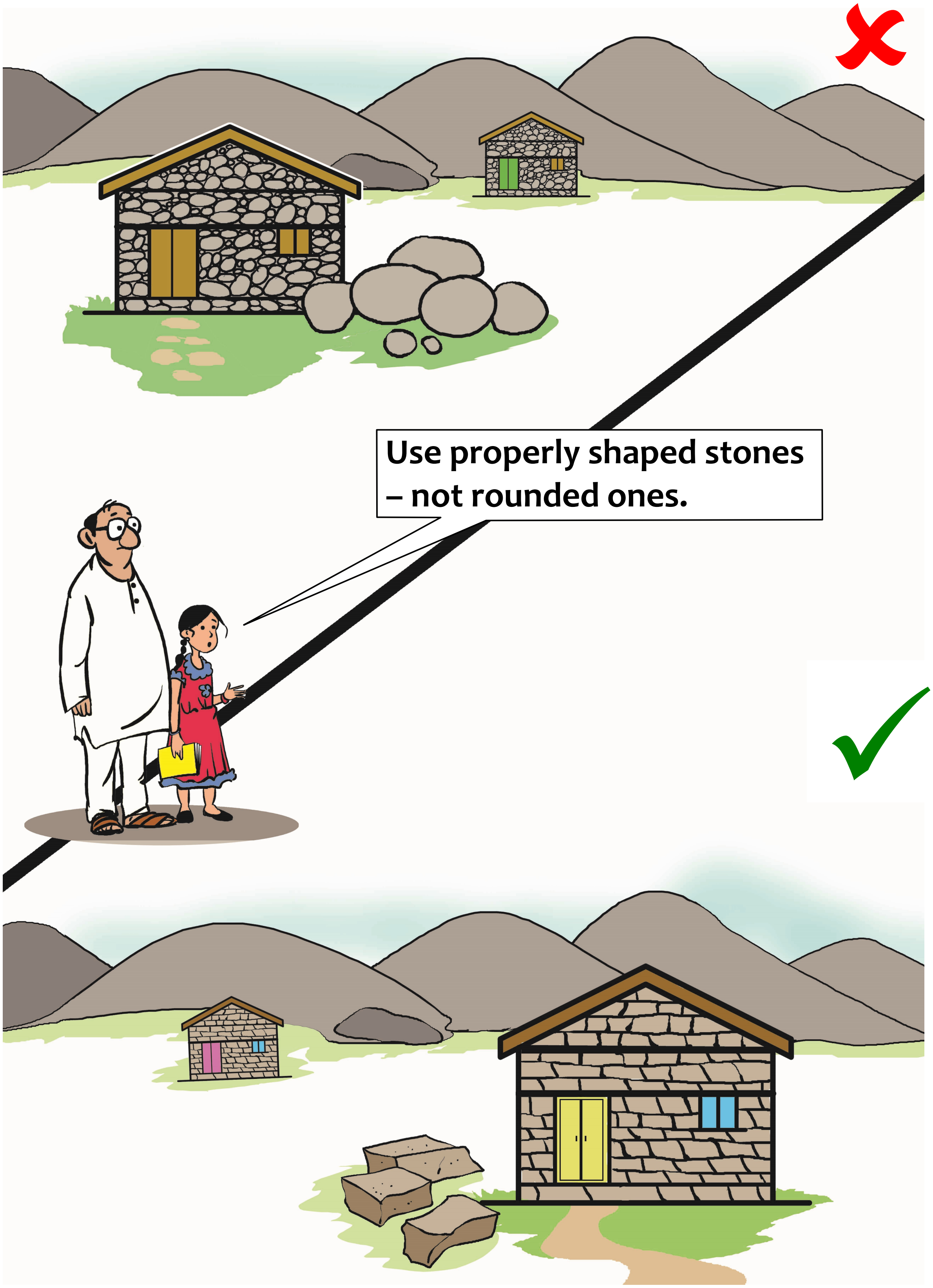


Joining Masonry Walls

Selecting Stones

Construction of houses in hilly areas is done largely with the locally available stone. In all, about 3.5% houses in the country are made of stone masonry. Often, rounded stones are available easily in the higher hills. In particular, stones are available at the *locations of landslides*, and *along the river banks* (especially at river bends, where large boulders rolling downstream get collected). These rounded stones are *smooth* and *do not provide enough grip to the mortar* to stick on the stone, thereby making the masonry walls *weak*. These rounded stones should not be used in construction of houses. Therefore, it is best to use the *regularly shaped stones*, which are *dressed* at least on the *top* and *bottom faces*, even if not dressed on all faces.

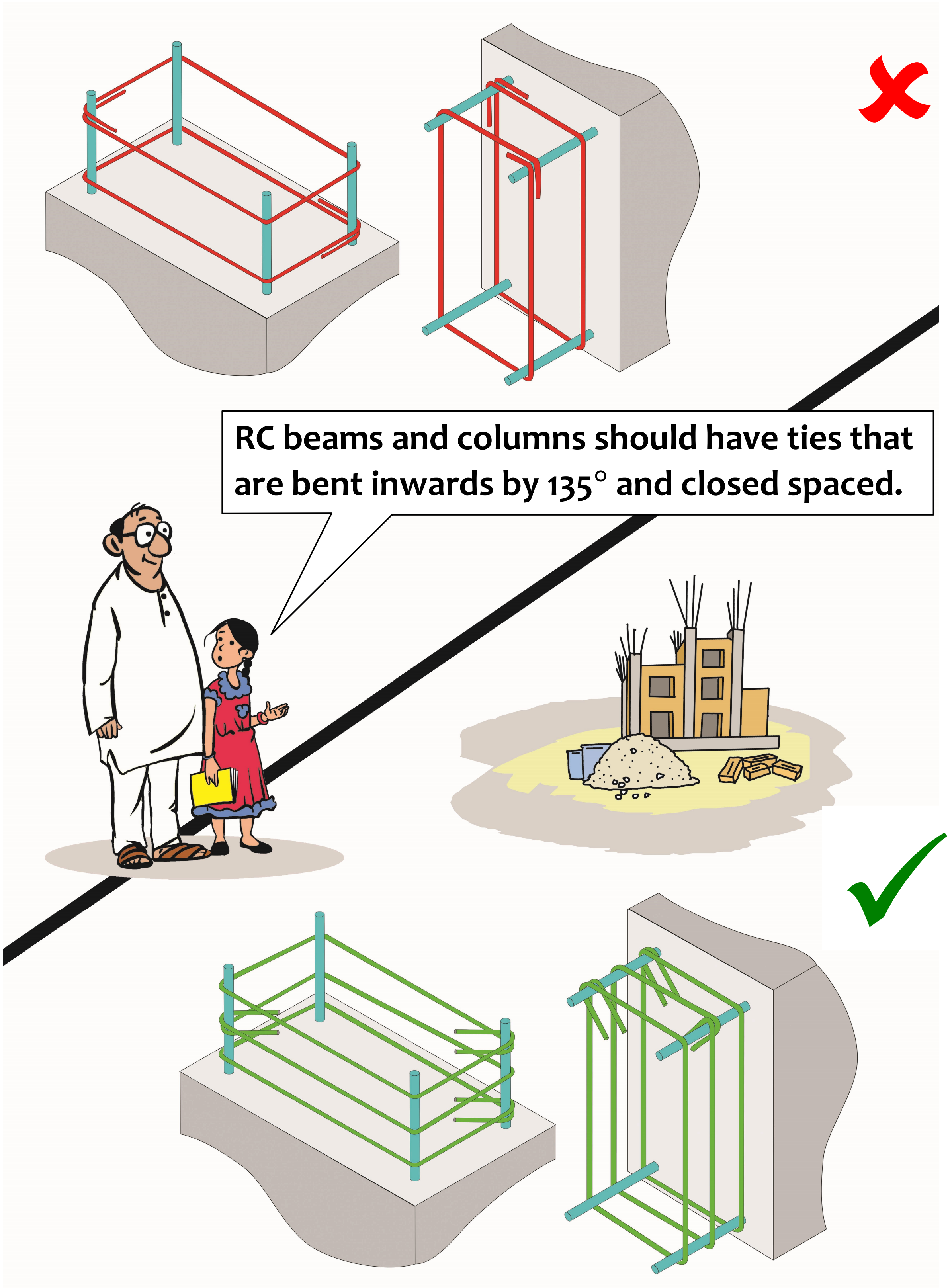
The thickness of stone walls depends on the type of stone, the effort required to break it into smaller units, and ease of lifting & placing the stones during masonry work. Walls of *300-350mm* thickness are common. When higher thicknesses are used, *through-stones* should be used at regular intervals in the construction of walls to protect the walls during strong earthquake ground shaking.



Selecting Stones

Providing 135° Hooks in Steel Ties

In RC buildings, beams and columns have *longitudinal bars* and *transverse ties* made of *reinforcing steel*. These ties play critical role by *holding the longitudinal bars together* and *preventing the concrete from bulging outwards* during strong earthquake ground shaking. Therefore, these ties should be prepared carefully by bending them in the form of closed loops ensuring that their hook ends are bent inwards into the core concrete of beams and columns. Bar benders should be trained to make these closed loops and hook ends with the bend going up to *135°*. Also, these ties should be spaced closely as per relevant Indian Standards.

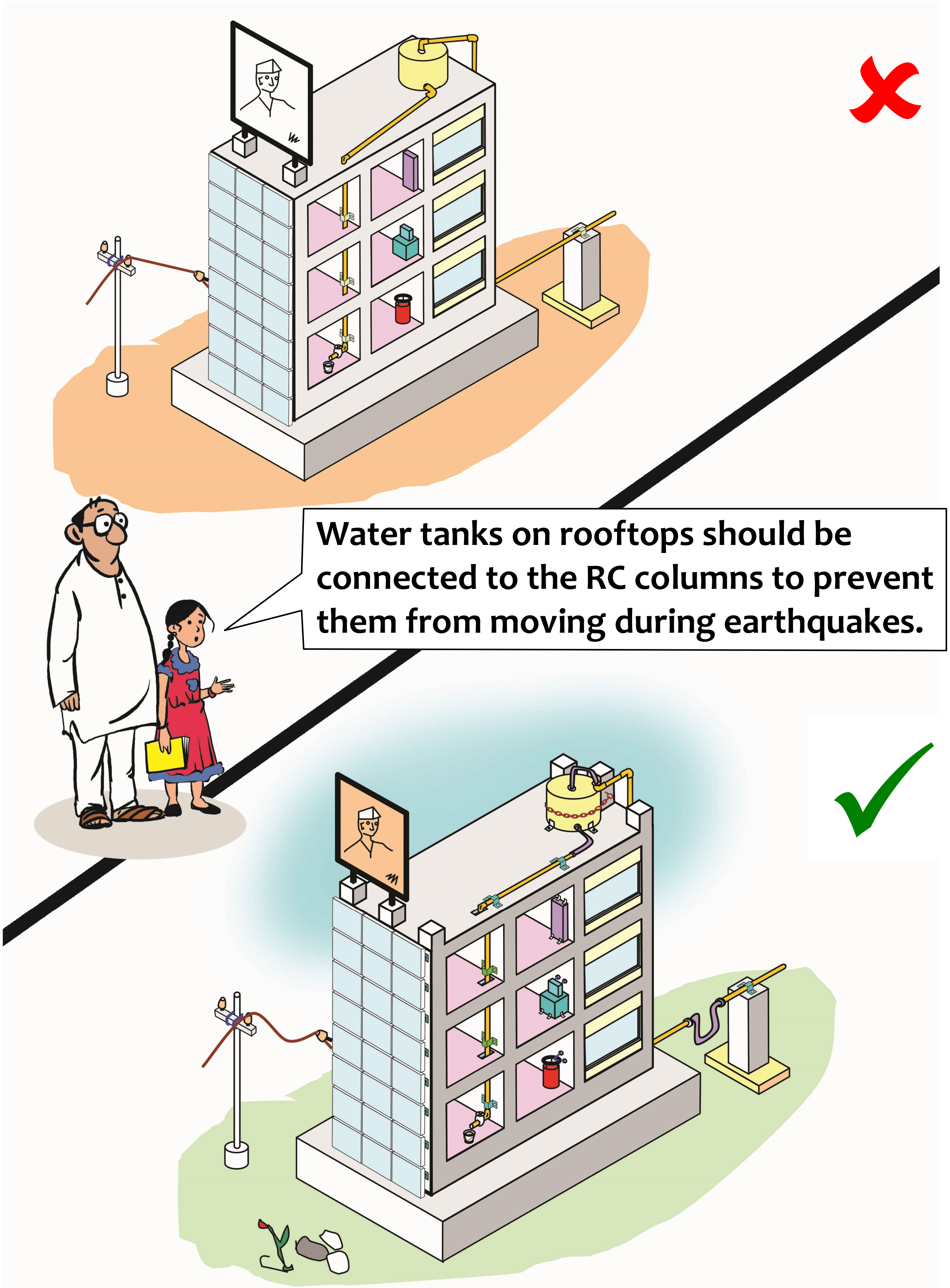


Providing 135° Hooks in Steel Ties

Securing Overhead Water Tanks

Commonly, plastic water tanks of 500-2,000 liters are placed on roof tops to supply water to houses. These tend to *rock*, *slide* and/or *topple* during strong earthquake ground shaking, and thereby causing potential threat to *life* and *property* underneath. They should be secured by connecting them to the *RC columns* in RC buildings, and to *RC slabs* in masonry buildings. The connections should be strong enough to carry the forces generated during strong earthquake ground shaking. Similarly, heavy objects placed on *lofts* in a house should be secured to *RC columns or slabs* in RC buildings, and to *RC bands or slabs* in masonry buildings. And, shelves or tall furniture or appliances in a house also should be secured to *RC columns* in RC buildings, and to *RC bands* in masonry buildings.

Also, long elements (like electricity, gas and water lines) should be held by the RC elements, but allowed to accommodate the relative movements between floors, and between ground and the building.



Securing Overhead Water Tanks

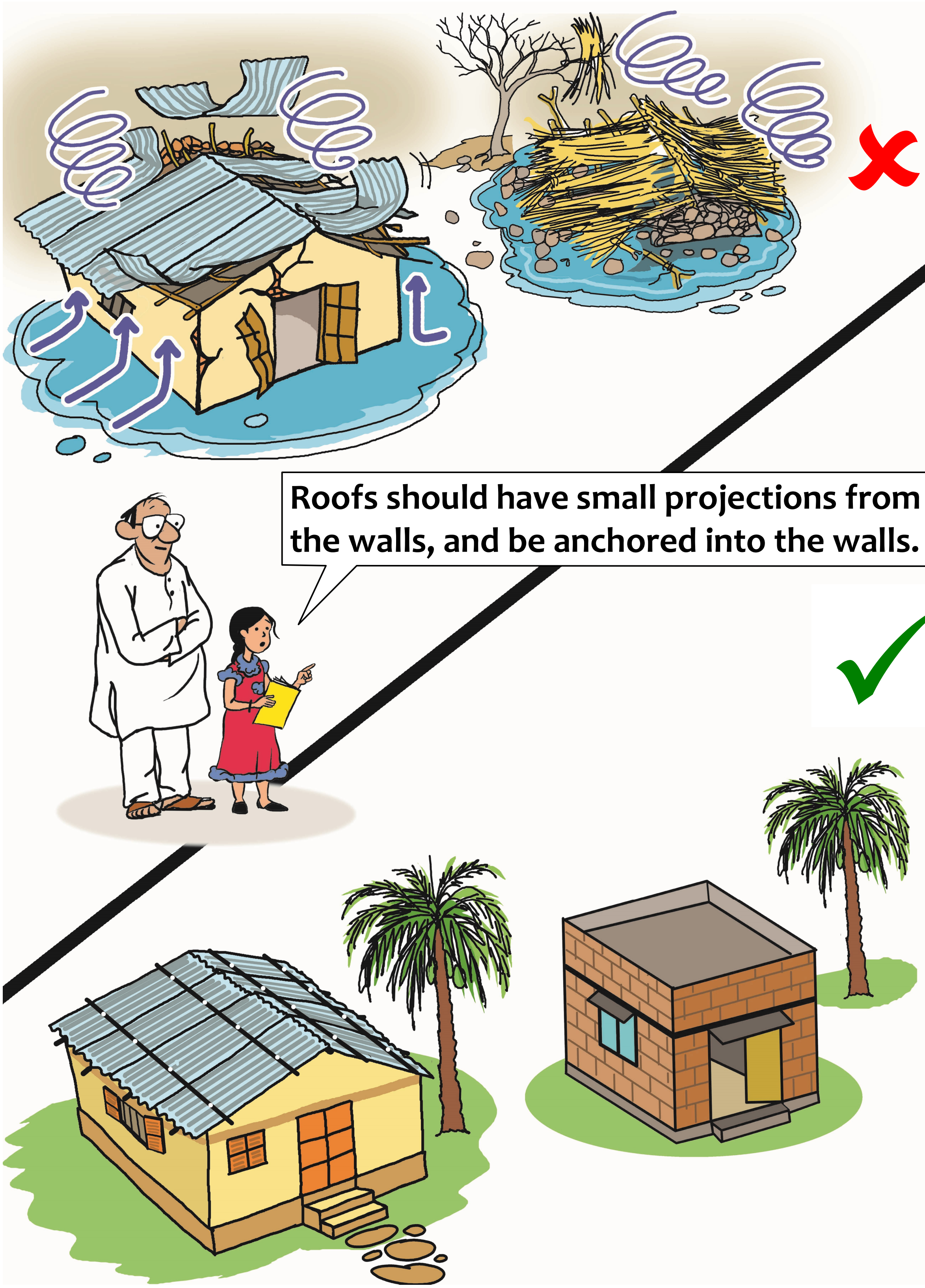
Securing Roofs of Houses

Cantilevers projections are most affected during strong cyclonic winds. These cantilevers can be vertical (like *hoardings*), horizontal (like *sunshades or balconies*) or inclined (like *sloped or hipped roofs*). The problem is severe when these cantilevers are light in weight and the slopes of the roofs are too gentle or too steep. Houses with the following *sloped roofs* are vulnerable: *thatch* roofs, *metal sheet* roofs, and *loose burnt clay tiles* (not tied to rafters or purlins of the roofing system). Thus, the following are essential:

(1) Roofs should have *slopes in the range 30°-40°*, and *anchored to the walls*; and
(2) Roof tiles should be tied to *rafters and purlins* of the roof system.

Typically, houses with RC slabs are found to be relatively safe under the usual cyclonic winds experienced along the coastline of the country.

Also, it is important to ensure that the roofs do not project beyond the *walls* or *column* supports by large lengths. These projections attract upward winds, and lead to the lifting of the roofs. Thus, it is best *to keep the projections small*, just enough to drain the rain water away from the wall.



Securing Roofs of Houses

5

PROFESSIONALS and ARTISANS

Competent Hands to Construct a House

Verifying Ownership of Land

When a potential home owner wishes to buy a plot of land from a person, she/he should go to the relevant Municipal Office dealing with *land records*, and check that the current owner of the land is the same person who is selling it, and that the land is clear for purchase. If yes, the potential home owner should get a letter from the *Municipal Office* stating that the land is *free from any encumbrance*. Once such a document is provided by the Municipal Office, it is important to get the *Seller* and the *Revenue Officer* to visit the site, and confirm that the land being purchased is marked on the Government's records. Only then the land should be purchased, else it *should not be*.

Even if the land is being sold by Government, it is best to seek a letter from the *Municipal Office* stating that the land is *free from any encumbrance*, before *making the payment*.

Verifying Ownership of Land

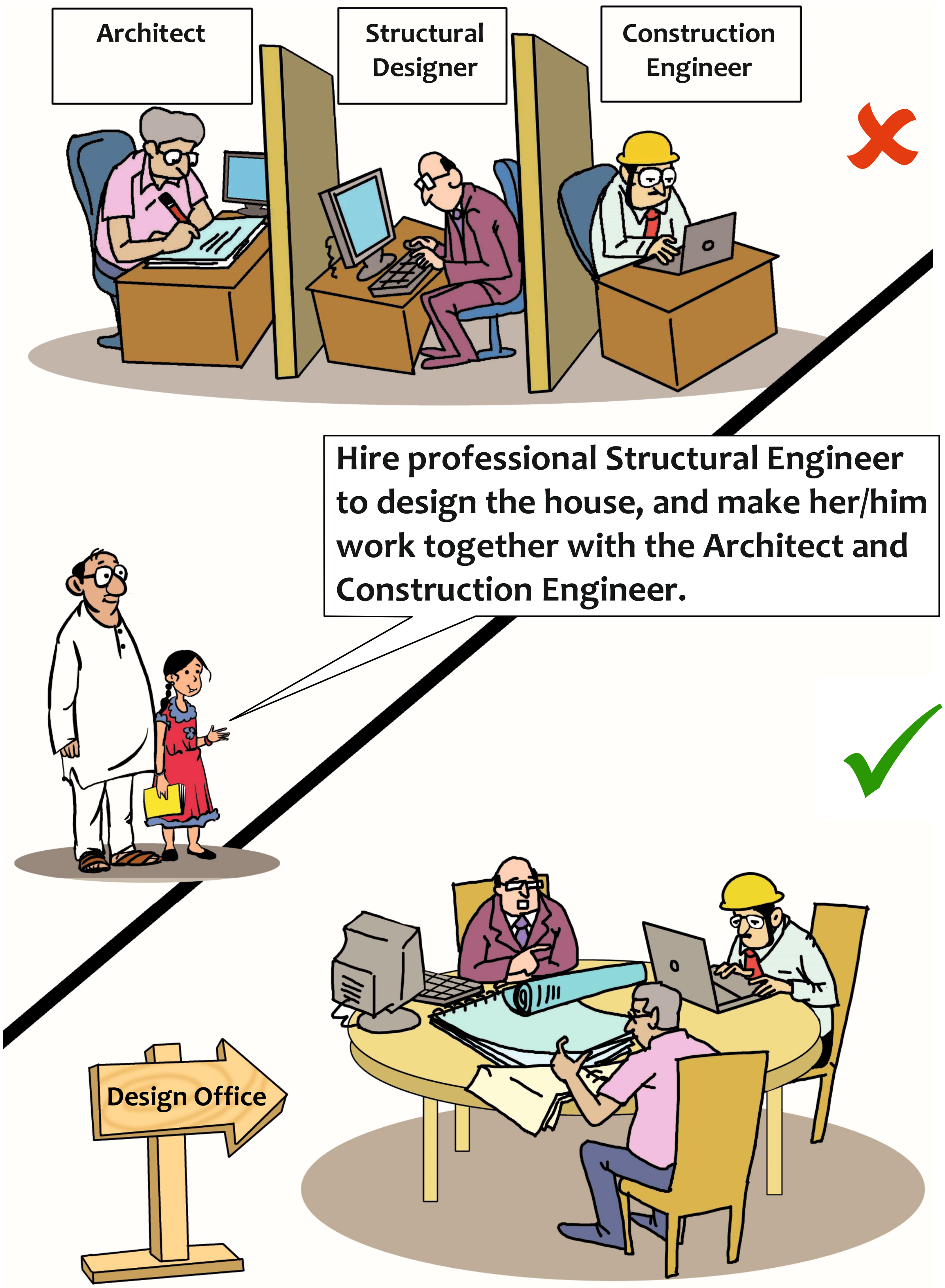
Marking the Plot of Land

The land to be purchased should be marked clearly with *pegs* or *stones* anchored into the ground at all corners of the plot. The plot of the land should be surveyed by a *Surveyor* recognized by the Government and in the presence of the *Revenue Officer*, before it is transacted.

Marking the Plot of Land

Hiring Competent Designer

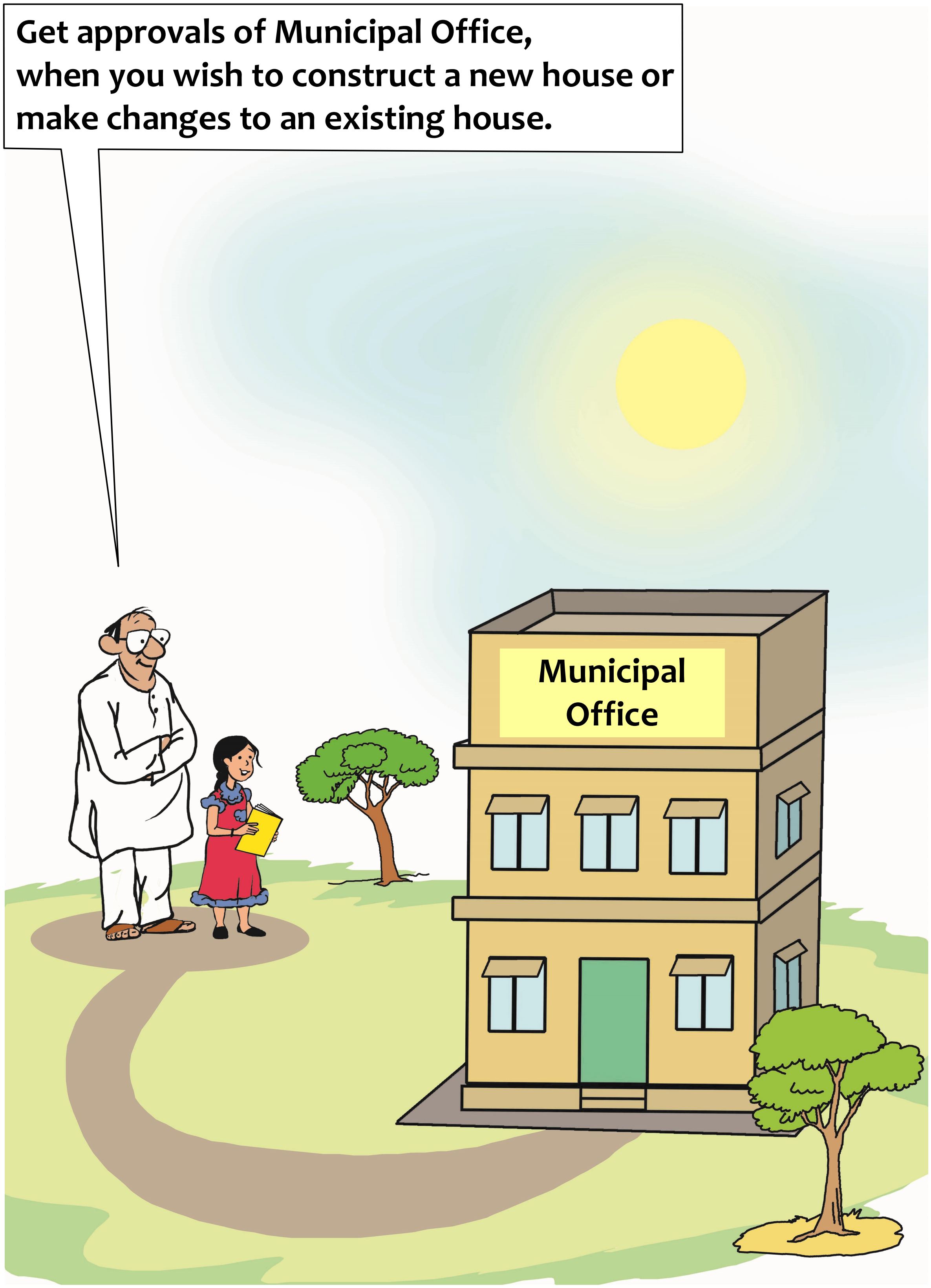
Architect, *Structural Engineer* and *Construction Engineer* are the three key professionals involved in the development of a house. If the house is small, the *Architect* alone is empowered to do all the *three tasks*. But, in bigger buildings constructed to have many houses, services are required of all 3 professionals. Designing *disaster resistant houses* requires the professionals to have *knowledge of the current best practices* and the *latest national standards* relevant to design and construction of houses. Thus, a *Structural Engineer* should be hired to design the house. Also, it should be ensured that the *Structural Engineers* have the required *professional competence*, namely they have the required *knowledge* (formally certified by the qualifications and certification of knowledge), the needed *skills* (reflected by review by peers of their past work), and positive *attitude* (demonstrated by *leadership*, *teamwork* and *enthusiasm* to do good quality work).



Hiring Competent Designer

Getting Municipal Approvals

After the said three Professionals have provided *the Good for Construction* drawings, the home owner should get an approval of the design from the relevant Municipal Office, and the permission to *start the construction* of the house. Such approvals are required not only when *constructing a new house*, but also when making *modifications to an existing house*.



Getting Municipal Approvals

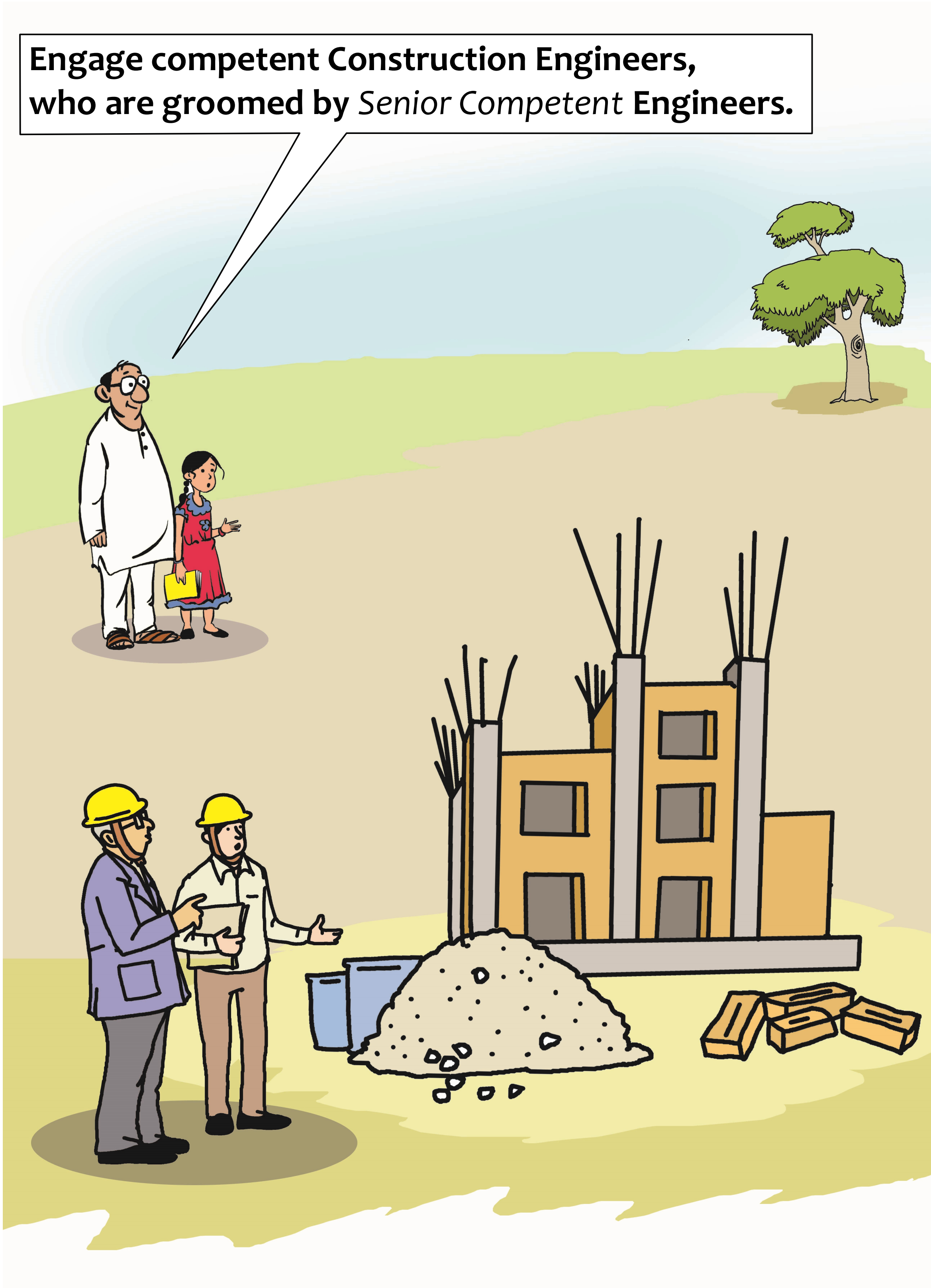
Employing Skilled Artisans

Even the best design will succeed only when the structure is faithfully constructed by the artisans, who *carefully and tirelessly implement* the details provided in the *Good for Construction* drawings. For achieving this, it is best to employ Skilled Artisans to build the House. They should have earned a *skill certificate* after due training at a Government-recognized *Training Center*.

Employing Skilled Artisans

Engaging an Engineer to Supervise

A *Construction Engineer* is one who has at least a *Bachelors Degree* in *Civil Engineering*. Construction is a responsible activity that determines the safety of both *people and property*. There are a number of fine details of construction, which are noticed by *Construction Engineers* through *experience* gained in completed projects. Thus, it is best to engage *competent* Construction Engineers, who are *groomed by competent* Senior Construction Engineers.



Engaging an Engineer to Supervise

6

DO's and DON'Ts

A summary of the Guide

Earthquake Safety

The following is a summary of the main points presented in this *Guide*, which need the attention of a *Home Owner* towards ensuring *Earthquake Safety*:

S.No.	DO's
1.	Ensure that the ground on which the house is being built is *competent*, either on *hill slopes* or in *plains*.
2.	Ensure that the building is: (a) neither *too long* nor *too tall*, (b) *simple* without any bend in plan, and (c) *uniformly wide* along the height, if not wider at the base.
3.	Ensure that masonry houses have walls with: (a) *regularly shaped* masonry units, (b) *bands*, (c) proper *masonry courses*, (d) relatively *small door and window openings*, which are away from wall corners, and (e) *buttresses* supporting long walls.
4.	Ensure that RC buildings have: (a) *structural walls* along the full building height, (b) *135° hook ends* in transverse ties, and (c) additional *horizontal RC elements* to break slender masonry infill walls into smaller panels.
5.	Ensure that *good quality materials* are used in construction of the house. In houses built of stone masonry, only *dressed* stones should be used.
6.	Ensure that masonry and RC works are *cured* for the prescribed duration using potable water.
7.	Secure properly the following *to RC members* and never to masonry walls: (a) heavy objects (like *water tanks*), and (b) utilities (like *electric*, *gas* and *water* lines).
8.	Seek services of competent *Professionals* for design and construction of the house, and skilled *Artisans* for construction.

S.No.	**DON'Ts**
1.	Do not purchase any land for constructing the house, if *it is under dispute*.
2.	Do not start construction until the plot of land is *marked by the Surveyor* from the Municipal Office, and *approvals are provided* for construction by the Municipal Office.
3.	Do not use false ceilings excessively in the house.
4.	Do not use *excessive appendages* (like façade stone) or *large sized glass windows* in the house.
5.	Do not buy a house that is not certified to be *earthquake resistant* by a competent Structural Engineer.

Cyclone Safety

The following is a summary of the main points presented in this *Guide*, which need the attention of a *Home Owner* towards ensuring *Cyclone Safety*:

S.No.	DO's
Before the Cyclone	
1.	Ensure that the house is located away from *natural waterways*.
2.	Ensure that the house is located above *high flood level* of the locality.
3.	Check the integrity of the house construction, especially: (a) connection between roofs and walls, (b) fixture of roof tiles to roof purlins and rafters, and (c) doors and windows are shut snugly, and large glass windows are covered with wooden sheets/boards stiffened adequately with wooden runners, to resist heavy winds.
3.	Evacuate low lying areas and shift to *safer places at higher elevations*. Leave early to reach high ground or cyclone shelter well before the arrival of the cyclone.
4.	Anchor all movable objects close to the house, which can fly in strong winds and damage the house, *e.g.,* dead branches or dying trees; lumber piles, loose tin sheets, loose bricks, garbage cans, and sign-boards.
5.	Open sparingly only those doors of the house, which are on the wall opposite to those walls facing the wind.
After the Cyclone	
6.	After the cyclone flood water has receded, check if *any wall is damaged* or if *soil has scoured* underneath the walls of the house. If yes, *consult a competent Structural Engineer* to examine the house for safety, and only then enter the house for living.
7.	After the cyclone flood water has receded, *clear debris* from your premises immediately.

S.No.	DON'Ts
Before the Cyclone	
1.	Do not build houses with bottom of the foundations *close to natural ground level*, or resting on *reclaimed* or *filled soils*.
2.	Do not delay evacuating to high ground. Do not hesitate to leave the place, if asked to evacuate.
After the Cyclone	
3.	Do not operate any *electrical appliance*, until all the cyclone has passed.
4.	Do not get in *contact with cyclone flood water*; it may be *contaminated* with sewage, oil, chemicals or other substances.
5.	Do not try to go past flowing water, either *by foot* or *on a motorized vehicle*; you may get swept away or struck by an object.
6.	Do not *walk into an area* that is flooded; you may fall into an *open manhole* or *a pit*, which may not be visible.
7.	Do not consume any food that has *come in contact* with flood water.

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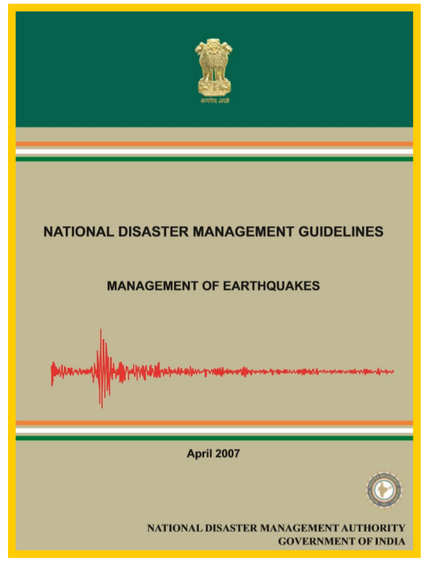
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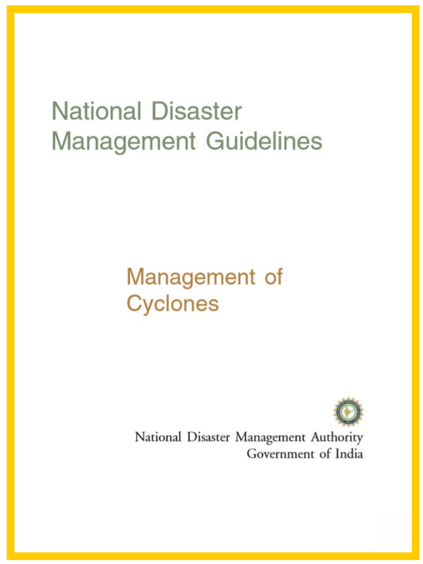
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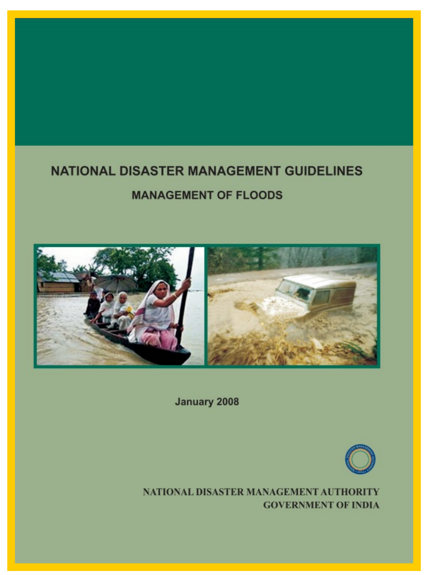
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Contact Us

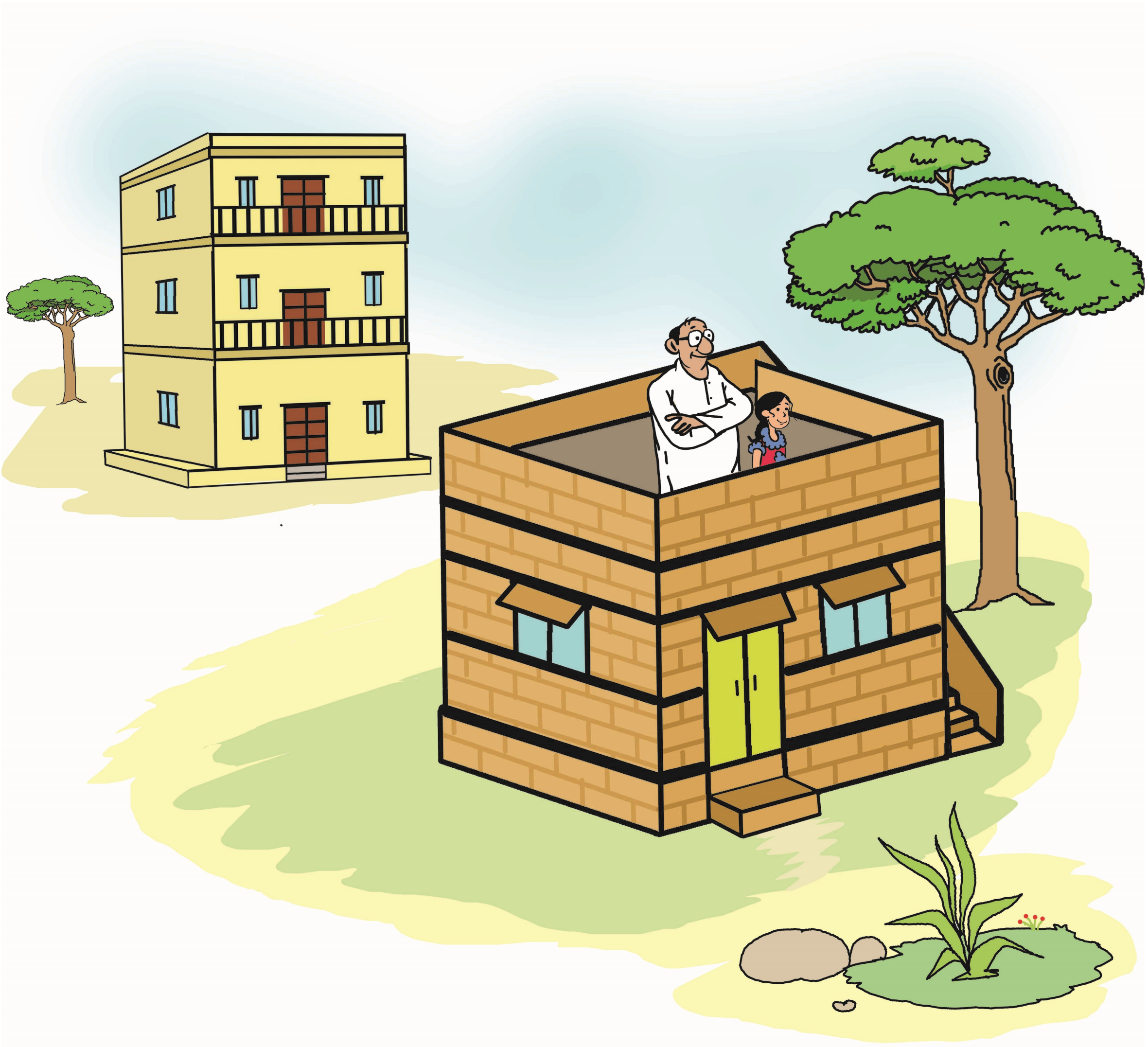
For more information on
Home Owner's Guide for Earthquake and Cyclone Safety

Please contact:

National Disaster Management Authority
NDMA Bhawan, A-1 Safdarjung Enclave,
New Delhi-110 029

Tel: +91-11-26701700

Web: www.ndma.gov.in



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for Earthquake and Cyclone Safety

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National Disaster Management Authority
Ministry of Home Affairs
Government of India