AN EPITOME OF INFORMATION USEFUL TO BUILDERS CONTAINED IN THE PREVIOUS REPORTS WITH REMARKS ON THE SAME.

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In a paper upon Construction in Earthquake Countries read before the Institution of Civil Engineers in 1886, (1) which was republished with additions by the Seismological Society in 1887, the author suggested several broad principles which ought not to be neglected by those who had to build to withstand earthquakes. The reason that the author was led to make these suggestions was because he had observed that they had often been neglected, and destruction had occurred where, if the builders had considered that the ordinary rules of construction are not altogether applicable when dealing with stresses which are applied more or less horizontally, it might in great measure have been avoided.

The principles suggested were as follows:—

1. To select a site for a building or to give it such foundations that it receives the least possible quantity of motion (in the following pages see the sections relating to sites and foundations).

2. To construct in such a manner that buildings may be

1. Proceedings of the Institution of Civil Engineers, vol. LXXXIII. session 1885-1886, Part I. Paper 2108.

2. On Construction in Earthquake Countries, by John Milne. Trans. Seis. Soc., Vol. XII,

best able to resist stresses due to earthquake motion, these stresses being often applied more or less horizontally.

In this section the principal subjects referred to were:—the unsuitability of archwork to resist horizontally applied stresses, the destruction which has so often arisen in consequence of coupling together parts of a building having different vibrational periods, as for instance brick chimneys and wooden houses, the ill effects of overloading, &c. In the following pages all these matters are again referred to, but with greater detail, and at the same time much matter which is more or less new has been added.

1. Choice of a Site.—A good site may often be obtained in a given city by taking advantage of the results of experience. Thus in the Ansei earthquake in Tokio it was shown that the greatest destruction took place on the low soft ground, while on the high hard ground the destruction was relatively small. Observations of this nature were made in 1883 at Cassamicciola and were then taken advantage of by the government when laying out the site for the new town. The occasions when observations like these have been forced upon communities have been very numerous, as for example at Lisbon in 1755, Port Royal in 1692, Belluno in 1873, in Calabria in 1783, San Francisco in 1868, Palcahuana in 1835, and Messina in 1726.

Although it is a general rule that the high ground which is hard is best, it must not be overlooked that there have been exceptional cases where buildings in such localities have suffered, as for example in Yokohama in 1880, and to a certain extent in Calabria in 1783.

In Tokio as the result of our feelings, it has been shown that more earthquakes are felt on the high ground than are felt upon the low ground. Instrumental observations so far as they have gone, and the results of of experience in 1885, have however shown that the most destructive motion has been experienced on the low ground, (See Distribution of Earthquake Motion in a small Area, by J. Milne, Trans. Seis. Soc. Vol. XIII.)

The best sites in a city may be determined should it be thought advisable by means of a specially organized seismic survey which involves placing a number of similar seismographs throughout the city and a proper comparison of the records they furnish. It has been shown that a seismic survey may be made for a small piece of ground say one quarter square mile or less in area. Such a survey was made of the compound of the late Imperial College of Engineering, now the Gakushuin, in Tokio. The results obtained clearly showed that if we had two similar houses on that compound at a distance of less than 800 feet apart, by a given earthquake one of these houses might be destroyed and the other suffer little if any damage. Until this survey was made it was not suspected that the difference in motion on two sides of so small a piece of ground could be so pronounced. Very wet ground or ground that is marshy notably forms a bad foundation. Steep sloping ground is also bad, the soil resting on such a surface often sliding downwards much in the same manner as tiles may slide from a steeply pitched roof. The sliding or tendency to slide is in all probability aggravated when the surface is loaded by a building.

The upper edges of cliffs and scarps where the motion of the free face of the cliff or scarps is naturally large, are also dangerous situations, and these more especially when the strata dip outwards.

2. FOUNDATIONS.—As a result of observations made in pit about 10 feet in depth, it was found that the motion at the bottom of the pit was in *strong* earthquakes very much smaller than it was upon the surface. These observations led the Author to the conclusion that great advantage might be gained by giving a building a deep foundation, this advantage being increased if the building rose freely as in a house with

an open area and a basement. That at least there is no harm in such a structure is attested by the fact that in all earthquake countries where there is legislation respecting building, cellars or basement stories are recognized as admissable. That relatively but little motion enters a building with such foundations is also attested by the fact that for such cellars vaulting is allowed, whereas for stories above the ground floor it has invariably been surpressed. The writer's experiments in this direction gave a measurement of the relative motion above and below ground showing that deep foundations were not simply withont danger but they might be advantageous. As these experiments made in a pit were few in number and as they are of so much importance to builders they should be repeated.

The Ischian regulations provide that buildings should be founded on the most solid ground. If, however, the ground is soft, a platform of masonry or cement must be formed which for a one storey building must be .70 m. thick and for a two storey building 1.20 m. thick. This platform must extend from 1 to 1.50 m. beyond the base of the building. In Manila it is stipulated that the foundations must be able to bear at least twice the weight that is to be placed upon them. When the soil is bad it must be piled or consolidated by a bed of hydraulic concrete and the foundation of a building must, as far as possible, be made continuous.

Another method of minimizing the quantity of motion received by a building is to give it free foundations. As an example of this, I may mention a room attached to my house which rests at each of its pillar-like foundations upon a layer of $\frac{1}{4}''$ cast iron shot placed between two iron plates. Short rollers placed at right angles might be equally effective. This building has stood for many years. It has not been disturbed by typhoons, and at the time of an earthquake a Seismograph inside the building shows relatively to the outside but little motion. Cast iron balls even if they are only 1 inch in diameter cannot be used. They are wanting in frictional resistance and the building is therefore subject to movements produced by wind and other causes. I do not bring forward this building as an example to be followed in practice, but only as an illustration of a principle which may have practical applications.

The ordinary Japanese dwelling house rests loosely on the upper surface on boulders or stones planted in the soil and therefore it is difficult to conceive how it can receive the whole of the motion imparted by the shaking ground to its stone foundations. In temples and other large buildings with heavy roofs which are so common in the country, beneath the supporting timbers and the superstructures there is usually a multiplicity of timber joints which at the time of an earthquake yield and therefore do not communicate the whole of the motion from below to the parts above. In the great earthquake of Ansei, 1855, so far as I am aware, the whole of these buildings remained intact.

Certain roofs which are of considerable span in the Engineering College at Toranomon were built so that they rested freely on the supporting walls, the object being that they might remain so far as possible, resting freely on the walls which moved beneath them. Although they have experienced many tolerably severe shakings hitherto, they have remained uninjured. These examples show, especially for the horizontal component of motion, that if a small building is not firmly attached to its foundations or that if parts of a building have connections between them that readily yield, it is difficult to cause such a building to move or swing, and that by a proper application of this principle destruction may be and has been avoided. For foundations I should only recommend the free foundations for *small, light* buildings erected on *very soft* ground. For ordinary dwelling-houses, and especially for heavy structures covering a considerable area, the writer is inclined to the opinion that the solid continuous foundation on the hardest ground, if possible surrounded by a free area, are the best. One objection to the loose foundations for a large building is that different parts of the same building do not simultaneously receive momentum in the same direction, and also in large earthquakes there is in actual wave-like motion of the ground.

3. ARCHWORK.—An ordinary arch is undoubtedly stable for vertically applied forces, but for horizontal stresses it is one of the most unstable structures that could be erected. Archwork has so often been the cause of ruin when shaken by an earthquake, that in Italy and Manila special rules have been drawn up respecting such structures. Thus in Manila intersecting vaults are not allowed, and ordinary vaults are only permissible when strengthened in a particular manner by iron. In Liguria vaults can only be used in cellars, but even then the rise must be at least $\frac{1}{3}$ of the span. The law of Norcia also only permits the use of archwork in cellars, and their thickness and method of construction is defined. In Ischia archwork with a rise of $\frac{1}{3}$ of the space and with a thickness of .25m. at the crown may be used, but only in cellars.

Speaking generally, the use of archwork above ground has been prohibited, and if it has existed after an earthquake all governments who have paid attention to building have ordered its removal. Underground its use is permitted providing that the arches are not too flat. This, however, only tells us that the motion beneath the surface is too small to destroy even a bad form of structure, and therefore such a form of structure, providing it is underground, is allowable.

In the second report in this volume, p. 45, instances are given where archwork in Tokio has been cracked by exceedingly small earthquakes. In case of a severe earthquake it is not unlikely that much of the archwork in buildings like the shops in the Ginza and in public structures will suffer very severely. If for architectural reasons it is a necessity that arches exist, these should not be too flat, of a specified thickness, be protected by an iron or wooden beam, and curve into their abutements. The Ligurian regulations provide that above windows there should be two iron bars.

4. Doors ad Widows.—In the building regulations for Norcia and Ischia it is stated that openings should be placed vertically above each other. It appears to the writer that if we have a series of openings like doors and windows in a wall placed vertically above each others it is very much the same as if we had here and there built our wall with the joints of bricks or stone continuously above each other, that is to say we have destroyed the unformity of the wall by lines of weakness, which will readily give way to horizontally applied stresses.

The subject is not one of great importance, but it appears that every successive horizontal line of openings ought not to be above each other, but so arranged that any line of openings when regarded vertically is as much broken as possible. (See p. 55.)

To arrange doors and windows so that they may form ready means of escape is certainly a matter worthy of attention.

An important point mentioned in the Ischian law is the position of doors and windows relatively to the freely vibrating end of a building, the limiting distance being 1.50 meters. Similar regulations are found in the laws of Norcia and Liguria. This distance should if possible be made to depend upon the materials of which a wall was constructed, its dimensions, and the size of the openings.

5. Chimneys.—A very important point which constructors should keep before them is to avoid coupling together two parts of a building which have different vibrational periods or else to couple them together so securely that they move as a whole. In Europe the first writer who recognized the fact that builders often allowed one portion of a building to destroy another in consequence of their non-synchronism in vibration

was Bertelli, who mentioned the matter is 1887. The same subject had however, in Japan been written about experimented upon, and emphasized since 1880. In 1880 most of the wooden bungalows in Yokohama lost their brick chimneys in consequence of the wooden framing of the house swinging against them and cutting them off. By itself a chimney may stand, but when partially attached to a house, the house and the chimney are mutually destructive.

The rules regulating the construction of chimneys are but few—the Ischian law states that they should be isolated from the walls. That of Liguria that they should not be in the walls and not connected with the building. Chimneys not being much required in Manila, nothing is said about them. Experience in Japan has taught householders to build their chimneys as short and thick as possible, to allow them to pass freely through the roof and not to load them with heavy coping stones.

6. CONNECTION BETWEEN DIFFERENT PORTIONS OF A BUILDING.—We have now to consider the advantages to be gained by tieing the different parts of a building together so that they vibrate as a whole. Since time immemorial buildings have been tied together with iron or wooden rods, but sometime previous to 1868, when San Francisco was shaken, a patent, known as the Foye patent, was taken out to improve the construction of sea walls. This was made to apply to land structures, and I believe that the City Hall and other buildings in San Francisco are built upon this plan, which consists in tieing together the walls at each floor by transverse and fore-and-aft rods of steel or iron. A plan similar to this is that of Mr. J. Lescasse, described in this volume. It has been applied to several buildings in Tokio and Yokohama, p. 85.

For such earthquakes as these buildings have experienced, with the exception of one occasion when the chimneys of the German Hospital in Yokohama were more or less destroyed, they have stood well. This system, however, requires to be thoroughly executed, for if rods are too few or if the bearing surfaces are too small, rather than supporting a building they accelerate destruction, especially at points of contact. Such buildings, partly for this reason and partly on account of their expense, are not looked upon with great favour in Italy. The Ischian law specifies that if iron bands or chains are used they must act upon a large surface.

7. ROOFS.—The advantage to be gained by making the upper portions of any structure light are very great. When a building with a heavy roof is suddenly moved forward the roof by its inertia tends to remain at rest. The result of this is a tendency to cause a fracture between the lower part which has been moved quickly and the upper-part which has tended to remain at rest. In all earthquake building regulations special reference is made to roofs, which must always be light, the material recommended being iron, zinc, or felt, ordinary tiles being only permissible for buildings which are not more than one storey high and not habitations. Certain kinds of tiles have sometimes been regarded as permissible, but these require to be properly secured, and it is specified that in such cases above the ceiling there shall be a floor of planks. Tiles require to be especially well fastened near to eaves.

The difficulty with roofs made of sheet metal is first to secure them so they shall not be disturbed during severe gales, and second to protect the interior of the house from heat. In Manila the first end is accomplished by a special system of bolting, whilst the latter is attained by a series of false ceilings.

The tie beams of trusses should extend at least 2/3 of the thickness of the wall if not over the whole thickness, and these rest upon wall plates. The truss recommended in Manila is the one with a central post (king post). For spaces greater than 7 meters, iron should be used, and trusses must be so placed that they do not act upon a weak point in the walls.

The Ischian law does not prohibit the use of flat roofs (*terrazzo*), but it provides that the framing of the same shall be strong and covered with materials which are fairly light.

The commission who reported to the Government, however, condemned such roofs.

8. Walls.—Walls like chimneys require to be light and strong. If heavy, and especially if loaded in their upper parts by copings and balustrades, they may be fractured and shattered by their own inertia. The height to which walls may be taken with safety depends upon the material of which they are constructed, the nature of the roof, &c. In Ischia it was suggested to limit buildings to 2 storeys or a height of 9.5 meters. The regulations, however, give 10 meters as a limiting height, and if they must be of simple masonry of *tuff* to a height of 4 m. with a thickness of .70 m. The committee suggested that external walls should be at least .30 m. in thickness, and that their uniformity should in no way be broken by openings for chimneys, pipes, &c. The Ligurian regulations allowed three stories above the cellar and a height of 15 m. The walls should be thick. If not built on the barrack system they should be at least 60 cm. and have a batter of 1/20 of their height. The Norcian regulations allowed 2 stories above the cellar and a height of 8.5 m. If a third storey existed it was to be removed.

Other suggestions have been made respecting the thickness of walls. They should be thicker than those ordinarily used, and their thickness was to vary with the material employed and the height of the structure.

In Manila, masonry walls of ordinary dwellings only reach the first storey, the upper storey being of timber. The walls for public buildings, however, may be higher. The length of a wall should not exceed twice its height unless it is supported by a buttress. Buttresses might be used at intervals not greater than twice the height of a wall. Their thickness must be 1/5 oj their height. Outside walls, transverse walls, and buttresses must be well united, while the corners of buildings should be supported by internal or external buttresses.

It would appear that the system of building with an upper storey of wood resting on and not built into the supporting wall, and a light roof, ought to do much towards insuring the stability of a building. A plan by which the weight of ordinary masonry may be reduced is to use hollow bricks.

In Manila, the regulations specify that upper walls must not rest on a floor.

9. Balconies and Cornices.—In Ischia, it was suggested that balconies should not project more than .60m. beyond the wall, and should be so constructed that they formed a part of the wall.

The regulations provide that cornices should not project more than .30m. beyond a wall.

The Ligurian regulations provide that cornices shall not project beyond the thickness of the wall to which they are attached. Roofs may not rest on cornices. Stone consols must run through the wall to which they are attached. In Manila, the regulations require that the balconies rest on the prolongation of timbers of the upper floor—otherwise a special form of construction is required.

From what the writer saw of the balconies or upper verandahs when in Manila, it appeared that many of them were without support on their outer sides. In such a case a balcony acts as a loaded cantilever, which either for horizontal or vertical motions of the building must cause considerable stress at its point of junction with the supporting walls. A careful examination of several hundreds of brick houses in Tokio showed that the walls were usually cracked at the points when they were entered by the beams supporting a verandah, notwithstanding the fact that the same verandahs were supported along their entire surface by vertical pillars rising from the ground. The writer's own opinion is that verandahs in any form are objectional features in a building constructed to withstand earthquakes.

10.—Shape and Orientation of Buildings.—In Liguria and Ischia, the regulations provide that a building shall be rectangular in plan and as nearly as possible square. Churches should be small and of the basilic form, with three naves and iron columns between the naves. The Norcian regulations also recommend a square form.

In Ischia it was suggested that buildings be placed so that the principal motion they were likely to receive might be along the diagonal of their plan. A result like this might be obtained by laying out the streets and roads in a proper direction. Rossi suggested that the most resistant sides of buildings should be placed at right angles to the nearest line of volcanic fracture, he holding the opinion that earthquake vibrations were propagated normally from the lips of such fractures.

The suggestion that buildings which have a plan which is rectangular or simple in its shape is a suggestion worthy of consideration, for it would certainly seem that such a building would be subject to less destructive stresses than one largely built up of wings and other projecting parts no two of which could be expected to vibrate in unison.

As to whether any great good may be gained by giving a building a proper orientation is not certain. In Tokio it appears that walls running in certain directions have been cracked more than others, and also that at the time of great earthquakes there has been more destruction in streets running in particular directions rather than those in others. Streets ought certainly to be wide, inasmuch that they would then form a refuge from falling débris.

11. Floors.—In Ischia it was suggested that the floor joists should rest with their whole thickness on the walls. If possible joists should cross each other at right angles and the floor planking be laid diagonally.

Bertelli proposes a system of flooring of iron beams connected by brick vaulting, or in place of this ordinary joists and planking, the beams on one storey being placed at right angles to those on another. In all cases the joists are to extend completely through a wall. The same regulation is also contained in the Norcian edict.

From these notes it appears that the intention of the authors of the regulations has been to utilize the floors to bind the building together as a rigid whole, and allow beams and joists to extend so far into walls that there is no danger of their being drawn from their supports.

12. CEILINGS.—Ceilings should be made in the ordinary manner with laths and plaster. But heavy ornamentation should be avoided.

13. STAIRCASES.—Although staircases if they are heavy might prove a danger to walls, their construction has not been regulated by legislature. Bertelli suggests that they should be constructed of pieces bedded in the walls as in the Tuscan system. If made by vaulting they are dangerous.

14. MATERIALS.—In all regulations special stress is laid on the quality of materials employed, and in all cases it is specified that these shall be of good quality. The Ischian regulations specify that for the principal framework of buildings chesnut must be used. In all cases square stones are to be employed. The lime must be good and be properly slacked with fresh water. Below ground hydraulic mortar must be used, and the sand used in mixing the mortar must be clean. These matters are treated upon in all regulations. In the regulations for Manila we find special remarks condemning the use of liquid lime, and recommending that stone walls should be kept wet while mortar is setting, that there should be good bonding, &c.

15. TYPES OF BUILDING.—The type of building most suitable for earthquake countries was discussed at considerable length by the commission summoned after the disaster in Ischia.

The objections to iron buildings was chiefly that of their cost, the difficulty of keeping them cool, and the fact that as they were a novelty it might be difficult to get them generally accepted. The commission, however, considered them durable and secure, and recommended that experimental buildings should be erected.

Timber buildings, although sufficiently strong and elastic to resist earthquake motion and at the same time impervious to heat, have the objection that they are not durable and are subject to fire. These objections may to some extent be overcome by the proper application of paints and chemical preservatives. Mixed constructions of iron and timber were not considered to present great advantages over those wholly made of timber. Buildings may be made of iron or masonry either by covering an iron framework with stone or brick, by building an iron framework inside the masonry walls, or by filling up the spaces between a double metallic framework with hollow bricks or other materials. Such buildings, although exceedingly good from many points of view, have the drawback that they are exceedingly expensive.

Having considered these types, from which it will be observed ordinary buildings of brick and masonry have been excluded, the committee described a barrack system of building which is the system they particularly recommenced for Ischia. Briefly such a building consists of a timber framework, well braced together, the spaces between the timbers being filled up with hollow bricks or some light material like scoria. The timbering is hidden by rough cast. Such a system was made compulsory in Portugal after the disaster in 1755. A building of this type, which may be made ornamental with an outside covering of tiles, is cheap, impervious to heat, and safe against earthquakes and fires. This suggestion respecting the system of contruction was adapted in the regulations issued by the government.

In the building regulations for Norcia, the barrack system is also the one to which preference is given. In the Manila regulations considerable latitude is allowed as to the system of construction—stone walls are considered best, but concrete or brick are also considered good. Although timber offers great resistance to earthquakes, its destructibility by fire, white ants, ordinary rot, and its inability to exclude heat prevent its recommendation. An iron frame work filled in with concrete is spoken of with favour. In the recommendations of a committee appointed to consider building in Manila, we find that stone is recommended for the basement and for the walls of the ground floor. This, with an upper story of timber, is the type of building which is common in Manila.

The military committee which was summoned in connection with the destruction in Manila in 1863 pointed out that destruction had occurred in all classes of buildings, but buildings with masonry supports had suffered more than others. This led them to suggest that only one kind of material be used in constructions and masonry supports should be avoided. Private buildings should be of wood. In all cases the limiting spans of roofs were specified, and the roofs must be light. Lieutenant-Colonel Cortés, who wrote at some length on structures in earthquake countries, shows that buildings must be light as well as strong, and this may be obtained by building their parts together much in the same manner that the timbers of a ship are bound together. Foundations and walls should be continuous. Timber-work and masonry should not come in contact, otherwise they may be mutually destructive.

After criticizing the system of building in Manila and showing how it may be improved, especially with regard to balconies and roofs, Colonel Cortés proposes as a foundation a timber platform almost on the surface of the ground from which rises a building with iron or timber framing footed on a dado of masonry, surmounted by a light roof. The wall framing may be filled with brick or plaster. Colonel Cortés' description are accompanied by an elaborate series of illustrations, some of which have been reproduced in this volume.

The Californian system of construction for which a patent has been granted, appears to be very similar to that proposed by Mr. Lescasse, the essential feature in which is to tie a masonry construction together at each story by a set of iron or steel rods which run from end to end, from back to front and from top to bottom in the interior of the walls of a building.

From South America but little information has been obtained. In Colombia the smaller houses have been built of thick adobe bricks, while the Spanish have used stone.

In Ecuador (Quito) occasionally a special room is built the walls of which are a wooden frame-work filled in with adobe. Many houses which have adobe walls three feet thick have only one storey, and there are few houses with more than one upper storey.

In Venezuela also the houses are low. In Mexico and Bolivia the houses are solidly built, while in Lima certain buildings are constructed lightly so that they may yield.

From Guatemala (San Salvador) I received from Messrs. Clark & Co., contractors, the drawing of a house supposed to be earthquake proof. It is of timber, well framed together.

These latter descriptions are particularly meagre, and for a fuller description of the systems to which they refer it is better to refer to the preceding pages.

16. Conclusions.—If we wish to mitigate the effects of earthquakes, one general conclusion that may be drawn from what has been written is that it is essential to select a site where we know from experience or by experiment that the ground suffers but slight motion. This will generally be the hard ground which is usually the high ground. Soft ground, slopes, and scarps should be avoided.

Having obtained our site we can follow one of two general systems of construction—either to give so much rigidity to a structure that it may be likened to a steel box, or to erect a building which is light but which has so much flexibility that it may be compared to a wicker basket—in either of these structures we ought to have lightness especially in their upper parts.

Amongst the former class of buildings which, from the materials of which they are constructed are unquestionably heavy, we have ordinary structures of stone or brick, (hollow bricks should be used by preference) rising from a deep foundation or free basement, walls of unusual thickness, well bonded and tied together. The roofs should be light, and the precautions respecting the position and form of openings, the arrangement of floors, roof trusses, and top weight referred to in the preceeding epitome carefully attended to. In this case we have a building where its strength more than outweighs the ill effects due to its weight. Such buildings are durable, and relatively safe against fire; they are suitable for all climates, but they are, relatively to all other buildings, exceedingly expensive. For this latter reason, this type of structure can only be employed for buildings of importance.

Amongst the light buildings which have sufficient strength and flexibility to overcome effects due to their own inertia when shaken by an earthquake are nearly all well constructed structures of wood or iron. The former of these, however, is neither durable, safe against fire, nor impervious to heat and cold. These objections may, however, be practically overcome, and wooden buildings are cheap. Iron buildings are relatively expensive, and without special arrangements they are too hot in summer and too cold in winter.

A type of building which offers the same advantages as a brick or stone structure does in relation to the danger of fire and in being suitable for changes in temperature, but which is very much cheaper and at the same time safe against all ordinary earthquakes, is a building constructed on the barrack system so strongly recommended in Italy. The framing may be of wood or iron while the filling in material which forms the walls, which ought to be as light possible, may consist of hollow bricks or a concrete made of light material. For this latter purpose the writer suggests that experiments be made with a concrete made of the pumiceous light scoria, of which in Japan there is such an abundance. He would also call attention to the possibility of employing cylindrically formed or pipe-shaped bricks, such forms being stronger than bricks of the ordinary rectangular section.

In all these buildings, whether they be of masonry, iron, wood, or built according to the barrack system, the roofs must be light, openings much be in proper positions, walls must be of moderate height, while floors, trusses, balconies, and the like must be constructed in accordance with the suggestions contained in the previous epitome. Ordinary structures in brick or stone are usually bad, while timber structures with a masonry front are worse. To resist earthquake motion we require lightness, strength, and if possible, a certain elasticity. Weight, unless it is accompanied by great strength, is a quantity to be avoided.

For Japan, for which this report has been written, for buildings of importance the writer suggests the use of brick. Let the buildings be placed in good situations, the brickwork well bonded and unusually thick, and let it rise from deep foundations. Roofs should be light. For ordinary buildings, unless the barrack system be adopted, the writer suggests that the system of construction remain as it is, with the exception that frameworks should have more diagonal bracing, roofs be made lighter, and the outside wooden surface be protected from fire. In carrying out these suggestions, the conclusions respecting general principles and details of construction arrived at in the preceding epitome must not be overlooked.