Inspection System for Old Public Buildings and Apartments in Colombo Municipal Areas

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ABSTRACT: Rating system for buildings in respect of safety against disaster is not readily available in Sri Lanka. Since, Colombo municipal area is the most populated area in Sri Lanka, in case of a disaster the number of causalities or lost will be high if disaster resilience of buildings is not considered. This research study concentrated on fire and structural disaster prevention of buildings in Colombo municipal area on which a thorough literature survey was carried out and some available test results on old buildings carried out by National Building Research Organisation were analyzed. It was found that by carrying out necessary nondestructive and destructive testing on buildings and checking whether they satisfy the available regulations in Sri Lanka, decisions on retrofitting or demolishing shall be made.

1 OBJECTIVE

The objectives of this research are

(1) Appraisal of selected old public buildings and apartments in municipal areas in Colombo, and

(2) Publishing a survey report on structural stability of public buildings in Colombo municipal area to facilitate the decision making on whether to retrofit or demolish and rebuild in order to reduce the risk of failure.

2 ISSUES AND PROBLEMS TO BE SOLVED

2.1 *Present situation*

Population density is very high in Colombo District when compared with other districts. Area of Colombo city is 699 Sq.Km and 2.5 Mn population live there, it means that more than 10% of Sri Lankan population live in 1% of the land (www.priu.gov.lk). In Colombo city apartments and large buildings are common. Head offices of most government departments, local government offices, ministries, companies, large hospitals, commercial buildings, large schools, universities and many public buildings are situated in Colombo district.

Some of the apartments are more than 25 years old. For example "Soysa Flats" apartments in Soysapura, Moratuwa were built before 25 years and in some of these apartments corroded reinforcement bars are visible. There are some government and public buildings built before 150 years.

Records indicate that the National Museum of Natural History also known as the Sri Lanka National Museum located in Colombo 07 was established in 1877; the Cargills Millers building is one of the oldest department stores in Sri Lanka, established in 1844 during British colonial rule; Colombo Medical School was built in 1870; Colombo Law College was built in 1875; the School of Agriculture built in 1884; Government Technical College was built in 1893, and University of Colombo created in 1913.It is apparent that these buildings should be checked for their structural stability.

2.2 *Issues and Problems IDENTIFIED BY THIS RESEARCH*

Among the many public buildings and apartments in Colombo city there is a large number of buildings which are more than 25 years. Whether such buildings are structurally strong and durable is a question. Since, sufficient data is not available to take such judgements, it is necessary to carry out a survey to obtain data.

In Sri Lanka fire regulations were published for the first time in 1997 by Institute for Construction Training and Development (ICTAD), Sri Lanka (1st edition-1997, 2nd edition (revised)-December 2006).

In Japan, since the 1948 Fire and Disaster Management Organization act came into force, the fire service has been steadily developed by the accumulated efforts by relevant parties and has played an important part in ensuring the people's safety. Fire prevention administration is well performed in countries like Japan.

In Sri Lanka, buildings built before 1997 should be inspected for fire safety. According to the Fire Chief, the city's fire brigade has no legal power to warn or take action against an institution for not adopting fire safety measures. However, Colombo Fire Brigade has been in operation since 1890. At present fire brigades in the country come under respective local authorities and are funded through local authority allocations.

3 IMPORTANCE OF THIS RESEARCH

This research is important because, failure of buildings by a natural disaster or due to improper design or the age of the building could cause loss of lives and damage to property. Number of causalities could be reduced by proper inspection and retrofitting. Information gathered from Wikipedia relates that after 1950, 72 numbers of bridges failed and 974 people killed. Further, total number of 43, stadiums, high rised buildings, escalators, hotels, commercial buildings, platforms, residential towers, walk ways, departmental stores, balconies, office buildings and shopping malls have failed and about 2235 people killed. In Sri Lanka, the old building that housed the Divisional Secretariat of Colombo, and also the District Disaster Management Coordinating Unit of Colombo district had a fire resulting much damage and the secretariat was later shifted to a newly constructed building.

4 USING JAPANESE METHODS FOR SRI LANKAN SITUATION

In the Japanese method of rehabilitation and resettlement after the disaster and the Great Hanshin-Awaji Earthquake in 1995, Great East Japan Earthquake followed by Tsunami and fire in 2011, earthquake disaster prevention in buildings is considered and economically also it is found to be beneficial.

Base isolation technique was introduced to old government building which was not common for old buildings in Japan. Designs of new building takes into consideration the seismic load and a system for resisting earthquake is in use. Commercial and office buildings typically have higher safe index. Safety of building is considered in the formulation of development and strategic plans. Preparedness for disaster is always active and private buildings also promote disaster effectiveness. Seismic effect is not very predominant in Sri Lanka, therefore seismic studies are not included in this research survey. Therefore, study will be based on fire safety and structural safety.

According to building specifications used in Japan, for fire safety, in special buildings such as theaters, hospitals, apartment houses and others, the interior surface of the walls and ceilings of habitable rooms and for the above use shall be finished with noncombustible, quasi noncombustible or fire retardant materials. Noncombustible or quasi noncombustible materials for the interior surface of the ceiling of habitable rooms and for the use in buildings having habitable rooms on the third or higher floors are recommended. In Sri Lanka we have to follow the fire regulations of ICTAD.

In Japan, to prevent failure of old buildings retrofitting methods such as concrete jacketing, steel jacketing, FRP wrapping and fire resistant paint etc. are in used.

For building fire safety in Japan testing methodologies are in use. Japanese building standard includes fire safety. Wooden built-up areas remain in many cities in Japan. Fire resistance is evaluated parts by parts for economical and safety reasons and the priority list of fire safety is listed below.

- Building fire
- City fire after an earthquake
- Life safety for handicapped people, and
- Performance- based code for international trade of materials, and cost-effective solution etc.

In Japan, hazardous materials are dismissed related to article 9-3 as per fire prevention administration. Cone calorimeter combustion analysis system is currently used as the test method which is a good and acceptable scientific procedure to analyze total fire behavior of materials. Cone calorimeter system to carry out combustion analysis currently is not popular in Sri Lanka, although it is very important.

Figure 1 shows fire testing in Japan. In Sri Lanka there is no laboratory having a similar test facility.

Figure 1: Building tested for fire behavior and laboratory fire testing arrangement

5 METHODOLOGY

The following methodology was developed in this study and by following this methodology, few old buildings were tested for structural integrity.

1. Survey on old public building and apartments from Urban Development Authority, Condominium Management Authority and others by telephone conversation, interview with authorized persons, via website, written request etc.
2. Identify and list the buildings to be inspected in liaison with UDA and Condominium Authority.
3. Develop a methodology for appraisal of selected old public buildings and apartments in Municipal areas in Colombo. (In this stage which type of buildings to be appraised, what is the age it can be considered as "old" etc. will be decided).
4. Survey and inspection of identified buildings (old public government buildings and apartments)
5. Testing: Nondestructive testing such as Rebound Hammer, Ultrasonic Pulse Velocity, Half Cell Potential and Cover Meter; Semi destructive testing such as Depth of Penetration & destructive testing such as Depth of Carbonation, extracting and testing of Concrete Core sample, Load Testing, Testing for building materials from old building and beam, column and foundation details by excavating, the apparatus like the Fire testing Equipment (for developing cone calorimeter test) and relevant standards and literature to be purchased and inspection shall be carried out at a subsequent phase.
6. Report on further actions to be taken
7. Publishing research findings and conducting awareness programmes.

6 TESTS CARRIED OUT BY NATIONAL BUILDING RESEARCH ORGANISATION

Few old buildings including 100years old government office building in Kollupitiya and 25 years old hotel were tested in order to find out the state of corrosion of reinforcement bar, resistivity of concrete, depth of carbonation and compressive strength of concrete core samples. Since test results were inter related a definite decisions were made. At the locations where depth of carbonation was high, resistivity of concrete was low. Reinforcement bars showed possible risk of corrosion.

Resistivity of concrete and conductivity of reinforcement bars were tested using half-cell potential meter which is an electronic equipment used to measure amount of corrosion in embedded steel bars and resistivity of concrete to corrosion. The decision was drawn as per the ASTM C876 and the Instrument Manual of half cell potential meter as shown in Table 1and 2:

Table 1: State of corrosion as per ASTM C876

Conductivity (V)	State of corrosion
V> -0.200	>90% probability nor rebar corrosion
-0.350 > V > -0.200	Uncertain
V< -0.350	>90% probability corrosion occurring
V< -0.500	Approx. half of the specimens cracked due to corrosion activity

Note: Positive readings, if obtained, generally indicate a poor connection with the steel, insufficient moisture in the concrete, or the presence of stray currents and should not be considered as valid.

Table 2: State of concrete as per the Instruction Manual

Resistivity	Resistivity of concrete which lead to likelihood of corrosion
$\rho \geq 12$ kΩ cm	good
$\rho = 8$ to 12 kΩ cm	uncertain
$\rho \leq 8$ kΩ cm	possible

The research was based on the above destructive and non-destructive testing methods from which the conclusion shall be made after analyzing results.

7 RESULTS

Figure 2 shows a core sample taken from the wall of the 100 years old government building in Kollupittiya which was tested for depth of carbonation. Carbonation was found to have occurred both sides and only small portion on middle part remained uncarbonated.

Figure 2: Sample tested for depth of carbonation

Table 3 – Case 1 -Results of the public building tested for determination of strength and durability

Member	Compressive Strength (N/mm2)	Depth of Carbonation (mm)	Average Resistivity of concrete (Ω)	Average Potential value of re-bar (mV)	Comments
Column	36	9	99	-213	Building has compressive strength of above Grade 30 concrete. However, carbonation commenced and corrosion activity is also uncertain, so it is necessary to protect from further carbonation and possibility of corrosion.
Beam	49	4	81	-200	
Column	40	6	74	-217	

Table 4 – Case 2- Results of the public building tested for determination of strength and durability

Member	Average Characteristic Strength (f_{cu}) N/mm^2		Depth of Carbonation	Reinforcement Cover	UPV Results	Comments
	Core	Rebound				
1st Floor Slab	38.5	33.5	Maximum 23mm in locations tested	Satisfied	Not tested	Strength and durability are at acceptable level
Columns	Not extracted	45.0	Not tested	Satisfied	Not tested	Strength is at acceptable level; but quality of the concrete is in "Poor" condition
Beams	Not tested	Not tested	Not tested	Not tested	Poor quality concrete	Quality of the concrete is in "Poor" condition

Table 5 – Case 2- Results of the public building tested for determination of strength and durability

Serial No.	Location/ Member	Core test		Depth of carbonation	Half-cell potential		Comments
		Extent of voidage (% excess voids)	characteristic compressive strength f_{cu} (N/mm^2)		Average resistivity (kΩ cm)	Potential value (mV)	
1	Wall 1	0.5	34.5	full depth of core sample (>145mm)	5.1	-113	Durability of concrete based on results of depth of carbonation and resistivity measurements are not in acceptable limits. Potential measurements showed that there is no rebar corrosion in this location.
2	Wall 2	0.5	47.5	not occurred in this location (0mm)	16	-	Strength is satisfactory. Durability of concrete based on results of depth of carbonation and resistivity measurements are not in acceptable limits. Potential measurements showed that there is no rebar corrosion in this location.
3	Wall 3	-	-	-	20	-137	Durability of concrete based on resistivity measurements is in acceptable limits. Potential measurements showed that there is no rebar corrosion in this location.

8 CONCLUSION

It is concluded that designing of infrastructures with consideration of disasters in Sri Lanka is essential in future and basically for the structures used by the public like schools, hospitals, assembly halls, government building, commercial building, and apartments. Further, the existing important and high rise buildings also to be checked for safety index and retrofitting shall be done if any required.

9 RECOMMENDATIONS

It is recommended to carry out in future a comprehensive study based on methodology developed by this study. The research findings will help to minimize possible structural and fire hazard in public buildings in Colombo city in order to ensure people's safety on lives, properties and valuables. This study should incorporate the following two steps:

1. Colombo Municipal Council or relevant authorities should take into consideration, the outcome of an appraisal report of an old building before giving approval for alterations.
2. Develop a hazard map covering vulnerable municipal areas for other disasters such as earthquake, structural failure due to age, flood, cyclone etc.