STRUCTURAL ENGINEERING

QUARTERLY JOURNAL OF

INDIAN SOCIETY OF STRUCTURAL ENGINEERS

ISSE

VOLUME 15-1

Jan-Feb-Mar 2013

ISSE Structural Audit Format

(See Page 5)

Conservation of Heritage Buildings

(See Page 19)

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STRUCTURAL ENGINEERS

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INDIAN SOCIETY OF STRUCTURAL ENGINEERS

ISSE

VOLUME 15-1, JAN-FEB-MAR 2013

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Editor : **Hemant Vadalkar**
N K Bhattacharyya

Fraternity News

WELCOME TO NEW MEMBERS

(OCT-NOV-DEC 2012)

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M	1246	Nandkumar S. Bane
M	1247	Prema M. Sarangi
M	1248	Kirti Kishor Kanade
M	1249	S. Sjreejith
M	1250	Dinesh Wasudev Gawatre
M	1251	Gogol Jibon
M	1252	Abhay S. Kulkarne
M	1253	Ravi Gangadhar Maske
M	1254	Giridhari B. Chandrabansi
M	1255	Lohit Avappa Havalagi
M	1256	Yogesh Raj URS
M	1257	Dhananjay Shivaji Pawar
M	1258	Umesh Ramchandra Hedgire
M	1259	Ashutosh Kaushik
M	1260	Manohar S. Velhal
M	1261	Milind Baburao Bankar
M	1262	Ramesh Shridhar Yelve
M	1263	Naveen Kumar Talapala
M	1264	A. Rumugam
M	1265	Amitkumar A. Sonawane
M	1266	Raghuram R. Guduru
M	1267	Rajeev Kumar
M	1268	Nikesh S. Abbad
M	1269	Milind S. Kulkarni
M	1270	Sayed Gulam Rasool
M	1271	Nitin S. Parab
M	Jin 31	Prashant Mahavir Kala
M	PM 32	Nickunj Eximp Entp P. Ltd.

Patrons : 32 | Organisation Member : 23 | Sponsors : 8

Members : 1271 | Junior Members : 31

TOTAL STRENGTH 1365

FIELDS CONSIDERED AS ASPECTS OF STRUCTURAL ENGINEERING

- Structural Designing & Detailing
- Computer Software
- Materials Technology, Ferrocement
- Teaching, Research & Development
- Rehabilitation of Structures
- Construction Technology & Management
- Geo-Tech & Foundation Engineering
- Environmental Engineering
- Non Destructive Testing
- Bridge Engineering

& Other related branches

AIMS & OBJECTIVES

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries of Responsibilities of Structural Engineer, commensurate with remuneration.
3. To get easy registration with Governments, Corporations and similar organizations all over India, for our members.
4. To reformulate Certification policies adopted by various authorities, to remove anomalies.
5. To convince all Govt. & Semi Govt. bodies for directly engaging Structural Engineer for his services.
6. To disseminate information in various fields of Structural Engineering, to all members.

Wind Tunnel Testing of Tall Buildings: When to carry out?

K. Suresh Kumar

ABSTRACT

Wind tunnel tests have recently been carried out for many upcoming tall buildings in India. However, there is some confusion in the design community with regard to when such tests are warranted. In the absence of clear recommendation in the Indian wind loading code, designers are at times having difficulty in deciding the need for the test and in some cases making the wrong decision based on inadequate information. In this circumstance, the authors feel information on when detailed wind tunnel studies should be carried out will be useful for the design community. The intent of this article is to provide this information.

Key Words: Tall Buildings, Wind tunnel testing

1. INTRODUCTION

Rapid growth of population and non-availability of land space in metropolitan cities of India has led to an unprecedented amount of construction of tall buildings. However, the design of tall buildings still mainly revolves around wind loading based on the Indian wind loading standard. Though wind tunnel tests have recently been carried out for many tall buildings, the industry/design practice is still coming to grips with how to make informed decisions with regard to aerodynamic design, better structural systems, need for detailed study etc. This article in particular focuses on when one decides to carry out wind tunnel test for a tall building.

The design of a tall building is significantly driven by wind loading since they hinder the free flow of wind resulting in high wind forces. Designers need to know the expected wind loads on the building so that they can work out proper resistance systems to counteract the wind loads. As buildings grow taller, wind loads can often govern the design compared with the other important lateral loading of earthquake force. Currently, the general trend in India is not to do any special wind tunnel studies and the building design is simply based on the wind load provisions in the IS 875 Standard believing that the code calculations provide the ultimate answer without knowing the pitfalls hidden in the standard [Suresh Kumar 2011a]. Contrary to the codes/standards, wind tunnel testing does physically simulate and predict the aerodynamic effect of the actual shape of the structure. Wind tunnel test results are more refined and accurate since properly executed studies also account for the influence of adjacent structures, site specific wind directionality, and the specifics of the structural system.

Some practitioners are unaware that the standard is derived from a set of wind tunnel experiments of buildings with simple geometries. Like any other Standard/Code, the Indian Standard also states its limitations as follows: From ***IS:875 Part 3 1987*** *(Page 5), "Note 1 – This standard does not apply to buildings and structures with unconventional shapes, unusual locations, and abnormal environmental conditions that have not been covered in this code. Special investigations are necessary in such cases to establish wind loads and their effects. Wind tunnel studies may also be required in such situations. Note 2 – In the case of tall structures with unsymmetrical geometry, the designs may have to be checked for torsional effects due to wind pressure. (Page 48) Note 9- In assessing wind loads due to such dynamic phenomenon as galloping, flutter and ovalling, the required information is not available either in the references of Note 8 or other literature, specialist advise shall be sought, including experiments on models in wind tunnels.*

Though not mandatory, the IS code is clearly stating the limitations of the code calculation methods and recommends wind tunnel tests for more complex cases. However, unlike other National Codes and Standards, the criteria for when to undertake wind tunnel tests are is not quantified yet. The information on such criteria in other codes and standards is reviewed in the next section.

2. INTERNATIONAL STANDARDS

2.1 Australian/New Zealand Standard (AS/NZS 1170.2 2011)

This standard clearly states that this provision covers buildings less than or equal to 200 m high. Further, in section 6, the provision states that tall buildings with fundamental frequency less than 0.2 Hz (period of 5 sec) is not covered in this code. Further, tall buildings with sway fundamental frequencies within 10% of each other with both frequencies less than 0.4 Hz are also not covered in this provision. According to this standard wind tunnel tests are mandatory for tall buildings when the fundamental frequency is below 0.2 Hz, the height is greater than 200 m, or whenever significant coupling is evident in the first three modes of vibration.

2.2 National Building Code of Canada (NBCC 2010)

This code enforces wind tunnel test for buildings with lowest natural frequency less than 0.25 Hz (period of 4 sec).

2.3 American Standard (ASCE 7-10)

This standard recommends special studies/wind tunnel tests for buildings with unusual or irregular geometric shape located in complex terrain/surrounding conditions. Further, special studies/wind tunnel tests are recommended for buildings expecting high dynamic effects from vortex shedding, torsional effects and aeroelastic instabilities such as galloping and flutter. The standard suggests to consider such high dynamic effects when any one or more of the following apply: (i) the height of the building is over 400 ft (~120 m), (ii) the height of the building is more than four times its minimum effective width, (iii) the lowest natural frequency is less than 0.25 Hz, and (iv) the reduced velocity ***U/(f.b***) is greater than 5; where, ***U*** is the mean hourly wind velocity (at ultimate limit state) evaluated at the top of the building, ***f*** is the lowest natural frequency of the building and ***b*** is the average width.

2.4 CTBUH Technical Guide 2013

This recent technical guide states that the building's sensitiveness to dynamic effects and cross wind loading which requires a wind tunnel test depends on many factors such as shape, exposure, slenderness, structural system and wind regime of the site location. A wind tunnel test is recommended if any one of the following applies: (i) The height of the building is over 120 meters, (ii) The height of the building is greater than four times its average width ***b*** normal to the wind direction over the top half of the building, (iii) The lowest natural frequency of the building is less than 0.25 Hz, and (iv) The reduced velocity ***U/(f.b***) at ultimate conditions is greater than five, where ***U*** is the mean hourly wind velocity evaluated at the top of the building, ***f*** is the lowest natural frequency of the building and ***b*** is the average width defined in (ii).

3. RECOMMENDATION

As noted in the previous section, a number of international standards have quantified the requirement for a wind tunnel study clearly. In line with the above, a guideline for the wind design of high-rise buildings has been recommended by Suresh Kumar (2011b) in 2011. Based on the past recommendations made by other international standards and project experiences in India, the recommendations shown in Table 1 have been made to assist the developers/architects/structural engineers in deciding whether to go for a tunnel test or not. In the opinion of the authors, in order to construct quality structures for the future and avoid possible safety and serviceability issues in tall buildings, guidelines similar to Table 1 should be discussed for adoption in the applicable Indian codes and standards.

Table 1 When to carry out wind tunnel test

Wind Tunnel tests are recommended when one of the following applies
1. Height is more than 120 m
2. Total height/(Average width B over top half of building) > 5
3. Lowest natural frequency < 0.25 Hz
4. Reduced velocity U/(fB) > 5 where U = ultimate wind velocity at top of building, f = lowest natural frequency, B = Average width over top half of building

4. REFERENCES

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About The Auther

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ISSE Structural Audit format

Manasi Nandgaonkar, Hemant Vadalkar and ISSE Team.

ISSE had Submitted structural Audit format to MCGM for implementation.
Member can use this as guideline for carrying out structural audits (inspection).

Structural Audit of the Buildings

The general health and performance of a building depends on its quality of maintenance. As a building grows old, ageing, use (or misuse) and exposure to the environment can affect the health of the building significantly. Therefore, it is advisable to monitor it periodically by taking a professional opinion. Structural Audit is a preliminary technical survey of a building to assess its general health as a civil engineering structure. It is usually initiated as the first step for repair. This is similar to the periodic health checkup recommended for older people.

General Guidelines for the Structural Audit

Indian Society of Structural Engineers (ISSE) has evolved the General Guidelines for Structural Audit Report as given below, which will give the purpose for which the audit is to be conducted. It is more appropriate to term it as **"condition survey report" rather than Structural Audit.**

Date of Inspection	
Date of previous inspection report	
Name of Building	
Year of construction of building	
Drawings available Copy of structural drawing / Architectural is available / not available	
Mode of use Office / Residential / commercial.	
Type of structure RCC framed / Steel frame / load bearing masonry	
No. of floors for building / Wings / Flats	
No. Of lifts	
Type of underground, overhead water tanks.	
Last repairs and painting done.	Structural repair: Terrace water proofing External plaster Plumbing and drainage Pavement around bldg.
Any immediate repairs required.	No/Yes (As mentioned)
Present condition of the building.	Satisfactory Not Satisfactory – Minor damage / Major Damage / Severe damage Dilapidated / Unsafe

Areas to be assessed during the visual inspection of the building: -

Photograph of damaged area and marking on the plan is preferable and can be attached with the report. (Feed back forms from occupants are desirable.)

1. **The structural layout of the building.**
2. **Exterior condition of the building**
   - External walls / facades at various locations.
   - Columns / beams / slabs.
   - External plumbing / pipelines.
   - Over-head water-tanks.
   - Terrace / parapet walls / coping.
   - Chajjas.
3. **Condition of Common Areas:**
   - Staircases / lift wells / common passages
4. Interior condition of the building / flats
   - Additional and alteration to the original plan
   - Columns / beams / slabs.
   - Toilet leakages / the loft slabs.
   - Leakage at the sunken portion in kitchen.
   - Window frames.
   - Seepage from flooring and the dampness on the walls (for ground floor)
   - Separation cracks between wall and beam & column
   - Flooring.

The Structural Audit Report should indicate all the above observations, conclusions & general remedial measures to be taken for safety of the building.

However, the limitations of the Report include:

i) **The report is based on visual inspection of the accessible area and the data provided by the client only. The aim is to have a preliminary health check-up of a building. This report should not be treated stability certificate for the building.**

ii) In absence of design data & as built RCC detailed drawings, the resistance of the structure for earthquake forces / wind forces cannot be assessed.

iii) It may not be possible to identify the distresses in the structure below ground level. Detailed investigations if needed are to be carried out separately.

iv) After visual inspection if it is found, that non-destructive tests are necessary, these tests should be carried out separately.

v) If any repairs are desirable, further detailed investigation may be separately carried out to determine the method of rehabilitation and its cost estimate.

vi) Area covered by false ceiling and behind the furniture like cupboards, showcases even laminations can not be inspected and we can not comment on those hidden areas.

vii) Sometimes engineers are not allowed to enter and inspect the flat or if at all they are allowed the occupant tries to avoid showing the flat areas by telling him that he does not have any problem.

Civil / structural engineers **registered on the panel of structural engineers of Municipal Corporations** will conduct this 'Structural Audit' **in case of the structures, which are in the limits of Municipal Corporations.**

In case of the other structures, such Structural Audit shall be carried out by the Members of IEI / ISSE having 10 years professional experience.

The responsibility of a structural engineer is to submit a report to the society, covering the points mentioned in the format. The responsibility of taking any further actions based on the report rests entirely with the managing committee of the society.

General guidelines as preventive maintenance while carrying out any alterations in the flat: -

a. It is advisable to carry out all the interior decoration through the qualified architect/interior designer with knowledge about structures, plumbing & electrical. The interior designer should submit the actual working drawings to the society with proper certification by structural engineer who is holding a registration of Mumbai Municipal Corporation.

b. No structural member i.e. beams/columns/slabs should be tampered during interior changes under any circumstances.

c. Any cracks, leakages should be rectified immediately in consultation with a structural engineer.

d. Do not raise the floor level for any aesthetic reason if it adds considerable dead load to the slab.

e. No lofts should be constructed adding the load to the existing beams and columns.

f. Water supply lines and drainage lines should not be changed in haphazard manner.

g. Change in position and lines for wet areas must be avoided. Addition of wet areas should be done with proper care and without adding extra load to the floor.

h. If a new partition wall is to be added it must be of lighter material like lightweight blocks and not with the solid bricks and the work should be carried out in consultation with structural engineer.

i. All the pipelines, electrical cables and gas lines are to be checked regularly and should not be concealed by damaging the structural members like columns, beams and slabs.

External painting: -

External painting should be done periodically every 4-5 years with patch repairs if needed is a good maintenance practice.

About The Auther

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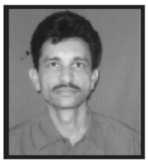

Hemant Vadalkar
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Report on ISSE's 15th Foundation day celebration

Hemant Vadalkar

Indian Society of Structural Engineers (ISSE) celebrated its 15th foundation day on 1st Feb 2013 at Institution of Engineers premises , Mahalaxmi Mumbai.

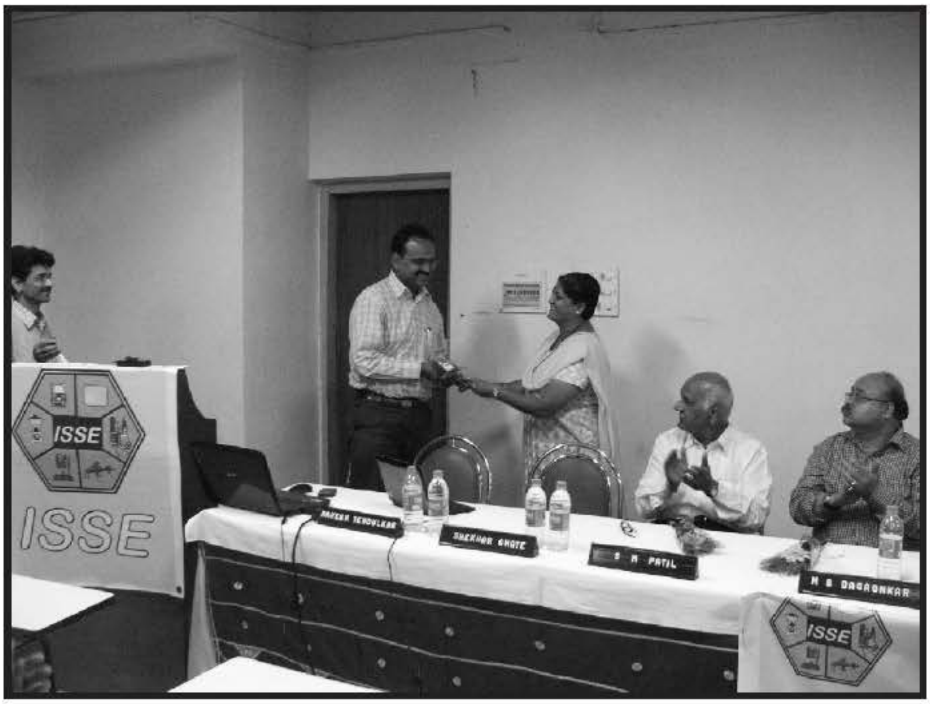
Chairman of Institution of Engineer Maharashtra local centre Mr. M. B. Dagaonkar welcomed all the guests and members. Secretary IEI Maharashtra centre S M Patil was also present. ISSE President Shri G. B. Chaudhary touched upon the history of ISSE and its active involvement in arranging the lectures , seminars and workshops for civil and structural engineers. Secretary P. B. Dandekar presented the activity report of ISSE during the last one year elaborating the lectures and workshops conducted by ISSE.
Secretary appealed to all the members for their active participation in ISSE activities.

Mr. Hemant Vadalkar appealed to all practicing consulting engineers to share their knowledge and experience through ISSE platform like lectures, seminars and journal. He also announced that the new ISSE website is operational and members can visit the site to know about all activities of ISSE and technical information.

A technical lecture on " Inspection and Testing of Bridges " was delivered by Mr. Mahesh Tendulkar. Mahesh has vast experience of Inspection & Testing of bridges, His team had inspected and tested more than 300 bridges in Maharashtra PWD. He shared his experience on various type of bridges inspected by him in Maharashtra. This includes old masonry piers, arch bridges, well foundations, RCC piers and abutments used in substructure and damage caused over the years. Interesting observations on superstructure including thick slabs, post tension girders and box girders were discussed. Corrosion of re-bars and post tension cables was the major problem faced by the bridges all around. Damage of cables in the anchor zone was observed in many cases . Failure of neoprene bearings was reported in some of the cases. He also touched upon the underwater inspection for piers and foundations. Standard inspection card for bridge inspection and monitoring has been developed for the purpose. The lecture was interesting and eye openers for the bridge engineers.

The program was coordinated by Mr. Hemant Vadalkar. It was attended by about 60 engineers.

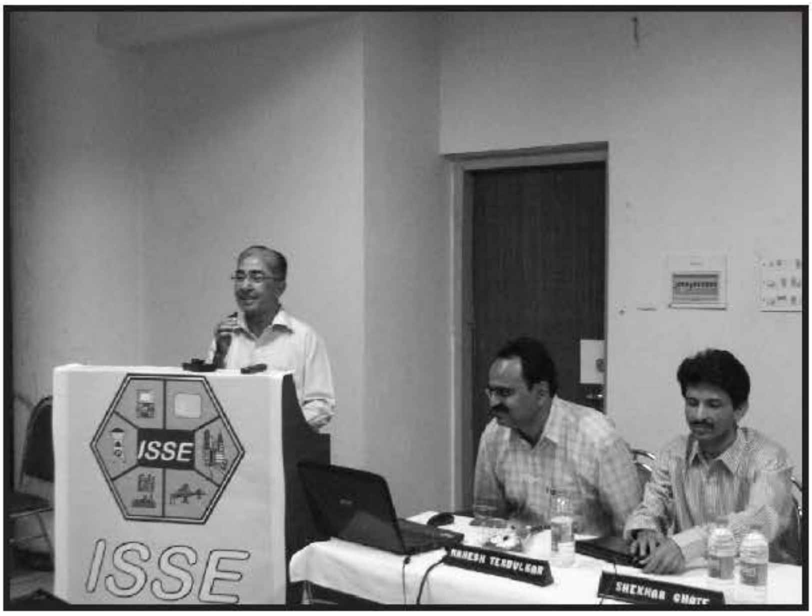
Mr. P. B. Dandekar Welcoming Mr. S. M. Patil



Mrs. Nandagaonkar felicitating speaker Mr. Mahesh Tendulkar

Presentation by Mr. Mahesh Tendulkar

Audience



(L to R) Mr. Raval proposing Vote of Thanks
Mr. Mahesh Tendulkar & Hemante Vadalkar

The History of use of stainless steel reinforcement bar in the Infrastructure building throughout the world

Contributed by : Outokumpu India Private Limited

The Construction Industry worldwide is becoming increasingly aware of the need to consider corrosion factors when designing new projects, following a number of high profile failures of structures built using traditional carbon steel reinforcing bar.

In addition the extent of maintenance being undertaken on concrete road bridges that are less than 20 years old is growing at an alarming rate. These ongoing maintenance costs are high, often exceeding the original construction costs for the bridge, and more worryingly, a detrimental effect on the environment due to the increased traffic pollution as a consequence of the delays.

The use of stainless steel in construction is not new, in fact in the 1930's a type of stainless steel similar to today's 1.4301 (304 type) was used in the reinforcement of the Progresso Pier in the Gulf of Mexico. (see picture on right)

The use of such an alloy in the construction of this pier at that time was revolutionary, and has allowed it to stay maintenance free in a very aggressive and demanding environment for almost 70 years. Conversely, a second bridge built alongside in the 1960's using carbon steel rebar was closed prematurely in 1982!

The World political climate is such that structural design consultants and engineers are now more aware of the need for durability and the need to use sustainable materials. The largest barrier to date has been the perceived extra cost and difficulty in use of stainless steel in both new build and repair projects.

Whilst the premature failure of major highway bridges in Northern Europe and North America can be partly attributed to the use of de-icing salts in winter months, the similar effects of carbonation and chloride ingress in industrial areas and marine environments respectively should not be overlooked.

Notwithstanding the important environmental and long term cost considerations, the aesthetics and negative aspects of premature failure of a new structure due to rusting must also be considered.

There are of course many ways in which chlorides can be restricted from reaching the carbon steel through the concrete media, these include:

- Increasing the concrete cover or reducing the permeability of the concrete by using cement alternatives, thus increasing the time it takes for the chlorides to reach the carbon steel.

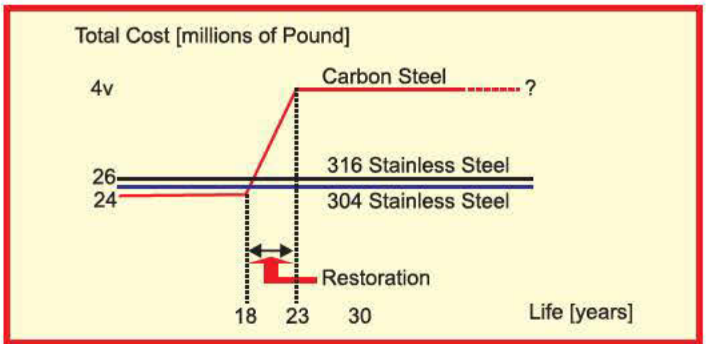
- Surface treatment by impregnation or coating to prevent the ingress of water and chlorides

- The use of epoxy coated carbon steel, although this is increasingly more difficult to control on site and should be restricted to simple pre-cast structures where the potential for dip coating is more controlled.

Whilst all of the above are capable of increasing design life of a structure, some may require ongoing maintenance, and all depend heavily on site workmanship, which in itself can be very unpredictable.

In addition, some of the above methods may well increase the complexity of the design and overall costs as a consequence, with little guarantee that the life expectancy will improve.

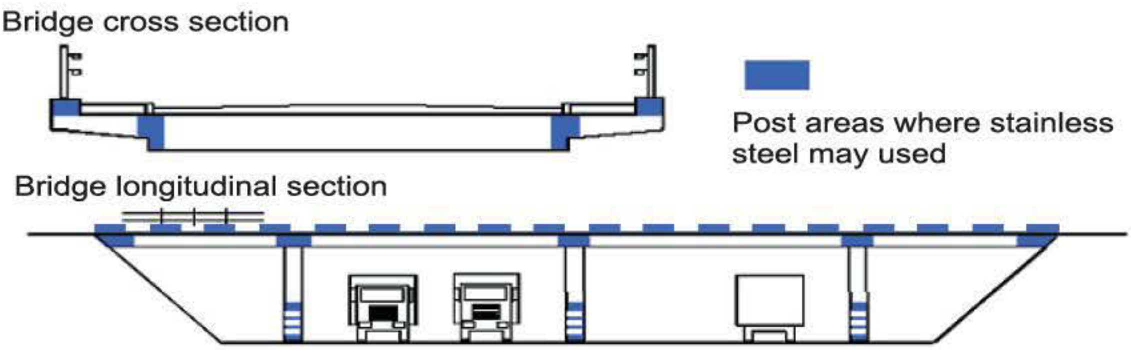
The “selective use” of stainless steel reinforcement as a long - term sustainable alternative therefore appears to offer the most cost effective solution, by replacing the “weaker” component, the carbon steel rebar. Selective use of Stainless Steel Re-Bar means coupling Carbon Steel Re-bar with Stainless Steel Re-Bar. In a neutral environment the potential difference of both metals is very similar, Carbon Steel being slightly noble to Stainless Steel Re-Bar. In concrete with a pH higher than 9 both metals are passive. With selective use the Carbon Steel will always be in the passive pH zone and the Stainless Steel RE-Bar exposed to either lower pH or chloride attack. In these circumstances both the Stainless Steel Re-Bar and the Carbon Steel Re-Bar remain passive.



Adapted from: S.R. Kilworth and J. Fallon "Stainless Steels for Reinforcement", 2nd Regional Conference on Concrete Durability in the Arabian Gulf, Bahrain Society of Engineers, 1995.

Cost analyses for concrete highway bridges have revealed that the selective use of Stainless Steel Re-bar increases the initial capital project costs by 0.5% to 10%, depending on the size and complexity of the bridge. This "modest" initial cost increase can be offset by reduced maintenance costs, as illustrated in the picture alongside :

In this example, the initial capital cost increase amounts to 4% for Type 304 and 8% for Type 316. If "disruption costs" are added to maintenance costs, the argument in favor of Stainless Steels becomes even more compelling. In the case of repairs to strategic bridges or elevated highways these indirect costs



include lost productivity, wasted fuel, delays in deliveries etc. These costs may be difficult to estimate but can be very high for major highways. In the case of toll bridges/tunnels or harbour facilities, the loss of productivity and revenue can be determined more easily.

Typical selective areas of use are shown above, indicating the areas most at risk from chloride ingress and / or potential vehicle damage. By this selective use, the overall cost increase is minimal, and in certain bridge designs can result in an overall reduction in costs.

In the UK, the Highways Agency has recognised the importance of durability in design and have issued various design standards and advice notes to minimise the potential for expensive maintenance in the future.

When stainless steel is used in selective critical areas, then the HA advice note indicates a relaxation in the normal design standards if carbon steel were used, namely: -

- Reduced concrete cover
- Expensive bridge deck surface treatments can be omitted
- Increase in the allowable crack width

All of the above could have the effect of reducing the total amount of concrete required, and potentially the amount of reinforcement as a consequence.

To summarise, for new build and remedial works the selective use of stainless steel in place of carbon steel makes perfect sense.

Its properties are such that it mirrors carbon steel in all physical and load bearing properties, and can therefore be replaced "like for like." Furthermore ;

- It can be connected to carbon steel without fear of increased galvanic corrosion to the parent carbon steel.
- Austenitic stainless reinforcing bars also have low magnetic permeability, no costly maintenance or unscheduled repairs, reduced concrete cover and greater crack widths allowed and eliminates the need for expensive bridge deck surface treatments
- Duplex stainless grades have ductility and strength superior to carbon steel and reduce total life cycle costs when compared to carbon steel

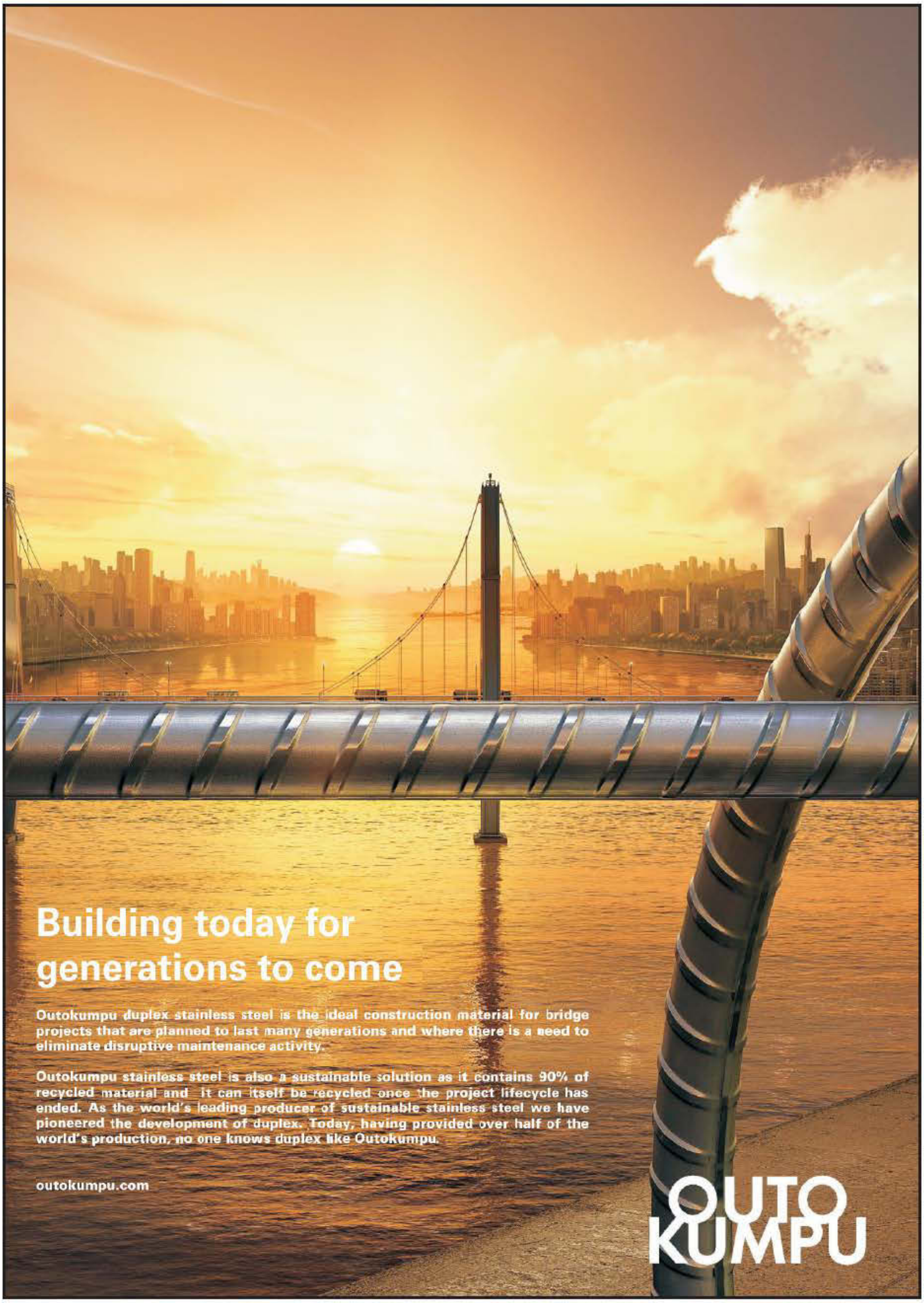
Pioneering Use of Duplex LDX 2101® in Concrete Reinforcement: a ground-breaking move towards sustainable infrastructure development at competitive cost.

The photograph alongside is the largest road and bridge project across the Brisbane river in Australia's Queensland history. Looking to the future, the new bridge is having a design life of 300 years. To ensure such a long lifespan, the bridge design specifies stainless steel reinforcement bar (rebar for short) in the most critical bridge structures: the splash zones of the two main river pylons.

While searching for a stainless rebar supplier for a product in the austenitic grade EN 1.4404 (ASTM 316L), using duplex stainless steel of grade LDX 2101® was suggested because the corrosion resistance of this duplex grade is close to that of 1.4404. Duplex stainless steel had never been used as reinforcing bars before, not to speak of LDX 2101®. The test results prove that LDX 2101® withstands a high corrosion environment. As a result, the second Gateway Bridge used LDX 2101® rebars and project is completed in 2011.

Outokumpu offers stainless steel reinforcement bars from Mumbai in sizes 8mm / 10mm / 12mm / 16mm / 20mm / 25mm and 32mm in straight lengths.

For more details, contact: Outokumpu India Private Limited, 609-612, Hemkunt Tower, Nehru Place, New Delhi – 110019. Phone: +91 11 46518440 or write to india.sales@outokumpu.com



Building today for generations to come
Outokumpu duplex stainless steel is the ideal construction material for bridge projects that are planned to last many generations and where there is a need to eliminate disruptive maintenance activity.
Outokumpu stainless steel is also a sustainable solution as it contains 90% of recycled material and it can itself be recycled once the project lifecycle has ended. As the world's leading producer of sustainable stainless steel we have pioneered the development of duplex. Today, having provided over half of the world's production, no one knows duplex like Outokumpu.
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OUTO KUMPU

A MICRO-LOOK AT CONCRETE IN PERFORMANCE

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Preamble:

Concrete is considered as the most versatile material of Construction since the invention of Cement about 100 years ago. The Cement Concrete has changed the Construction Technology and advanced it continuously over the years. Variety of structures for the purpose of residential premises, commercial towers, industries, dams, ports, bridges, flyovers, tunnels, roads, runways, precast & pre-stressed products and what not have emerged in concrete and are in service of mankind. The Concrete Technology has been evolving continuously with inputs of Research and Developments in the Materials of Construction and Methods and Technologies of Construction mainly due to the rapid pace of Industrialization and Urbanization.

Deficiencies in performance of Concrete have become more exposed during last 4 to 5 decades mainly due to the susceptibility to various aggressive factors. Durability of Concrete is not a static property, but depends on the phase changes in its service environment. The performance function of Concrete requires focussed attention on its porosity, pore size distribution, permeability and ion diffusion.

Concrete is the most heterogeneous system of ingredients mainly Cement, Fine Aggregates, Coarse Aggregates, Water and Chemical & Mineral Admixtures additionally. From such system a cohesive and dense mass of Concrete which is workable enough in fresh state and capable enough to sustain a variety of exposure conditions in its hardened state must be made. The variability of Concrete quality arises from the Materials available, the Mix Design and from the Process by which it is batched, mixed, transported, placed, compacted and cured. All these factors are difficult to be applied perfectly in all working situations of concrete making to expect to meet the durability specifications of concrete in performance.

Fresh Concrete :

Well made fresh concrete with optimum balance of ingredients in the mix design must exhibit performance of good rheological /workable concrete which is transportable for the required time, pumpable, placeable, and compactable to give superior properties in the hardened state.

The performance of hardened state of concrete is based on the factors such as:

1. Control of water content and water /cement ratio in the concrete mix
2. Better cohesive concrete mixes of uniform and consistent properties of fresh concrete in terms of workability and its retention and without mix segregation or losing pumpability.
3. Longer transportation times for mega project sites and RMC operations.
4. Timely deliveries of concrete through Ready Mix Concrete operating Plants in City areas without losing /harming, fresh /hardened concrete properties.
5. Speeding up the process of concreting through pumping capabilities.
6. Achieving concreting in normal pours/difficult pours of congested reinforcements and complex shuttering designs with good compaction.
7. Overcoming hot weather / cold weather concreting problems.
8. Achieving better finishability of concrete cast.
9. Making concrete mix designs with Supplementary Cementitious Materials such as Fly Ash Class C & F, Slag, Very Fine Slag, Microsilica, Metakaolin , Rice Husk Ash and other special cement additives and Steel / Polymer Fibers and with Superplasticizers and other chemical additives work in practice.

When the Cement reacts with water and the hydration reactions begin and progress, it is interesting to know what the Structure of hydrated cement paste and concrete develops and how the bonding of aggregates with cement paste takes place and what properties of concrete remain deficient which affect its performance vis-à-vis durability aspects of concrete.

Hydrated cement paste (hcp):

hcp is the binding medium between the aggregate particles of various size and shape and characteristics. Concrete, therefore, can be considered as a two phase material,i.e. of hcp and aggregates. Such a system is meant to make a material capable to develop its microstructure for a well defined structure-property relationship. It is at this stage of expectation of performance of concrete that the complexities of its structure begin to show up. The microstructure of the paste close to the aggregates differs from that of cement paste in bulk. The attractive van-der Waal's forces between paste and aggregates are similar, in principle, to those existing within the paste. The products of hydration of cement are relatively insoluble, and they begin to crystallize out and start filling the space occupied by water. At any point during the process of hydration of cement, the unfilled space will consist of voids and capillary pores. With the progression of hydration and decrease in capillary porosity, the moisture movement in the systems can become sluggish. The subsequent hydration of the unhydrated portions of large cement particles is believed to be a slow process of solid state reactions. The early hydration products, formed where there is plenty of water and empty space in the cement water system, consists of flocs of large crystals, which tends to entrap a considerable volume of voids. Since the hydration products crystallize out in the water-filled space surrounding the cement particles, researchers refer to them as "outer products". On the other hand, the hydration products formed from solid-state reactions, formed within the original boundaries of hydrating cement particles, are called the "inner products" and are more compact and poorly crystalline. It is such products of hydration which contribute to lesser porosity, the more such hydration products, the better and denser is the microstructure, leading to higher strength and lesser permeability of cement paste and concrete. The path of fracture goes through the outer products rather than inner products. The concept of outer and inner type of product is useful in appreciating the role of low water/cement ratio, superplasticizer and mineral admixtures for making better concrete in terms of high strength and low permeability.

Cement-Aggregate Interfacial Transition Zone:

The interfacial bond between cement paste and aggregates, its formation and development represent the weak link in the composition of concrete body. This phenomenon manifests in poor tensile strength and higher permeability of concrete. The coarse aggregate particles, depending upon their size, shape and surface texture, create spatial hindrance and cause inhomogeneous distribution of water in fresh concrete during mixing, consolidation and placement. Such particulate suspension has a tendency to differentiate into two phases, one richer in the liquid phase and the other richer in the solid phase than the desirable cohesive concrete mix composition. As a result, the local water/cement ratio in the cement paste next to the coarse aggregate particles becomes substantially higher than the water/cement ratio in the cement paste some distance away. The micro-structural in-homogenities thus developed in this transition zone are characterized by the presence of large pores and large crystalline cement hydration products. These factors play a critical role in determining the strength and permeability characteristics of concrete, which in turn strongly influence the durability performance of concrete.

Many properties of concrete are controlled by this interfacial bond and it has been studied from three points of view :

1) Microstructure of cement-aggregate interface;
2) Influence of processing and cement concrete chemistry;
3) Effect on engineering properties of concrete such as strength, permeability, toughness, shrinkage and crack formation.

In all these aspects, the cement paste aggregate interface, called the Transition zone, forms the critical area of observation. If concrete is subjected to any stress, the cracks first begin to develop in the transition zone. The macrostructure is the long range structure; the bond is distributed throughout the volume of concrete and it is associated with the size, volume fraction and surface area of the aggregates. It is related to bulk properties and, therefore both microstructure and macrostructure i.e. short range and long range structures must be considered, so as to relate the bond to properties. The thickness of the interfacial region is often measured to be about 40 - 50 microns for a typical well proportioned concrete and 50 - 80 microns for ordinary concrete, and the mean spacing between aggregate particles is generally only 75-125microns. Thus, a great portion of cement paste belongs to interface zone and only a small part belongs to bulk cement paste. The criticality of this bond formation and development in its interfacial zone, microstructure and macrostructure are therefore of great significance.

During mixing, the aggregate particles are in vigorous motion relative to the surrounding cement paste. A freshly mixed on concrete is a particulate suspension, which is far from its equilibrium state and possesses very non-linear and irreversible characteristics. Observations of the behaviour of fresh concrete under vibration suggests that it is mildly thixotropic in nature, i.e. becomes thinner when distrubed and thickens again when left alone. The workability of fresh concrete is very important practically and it is largely governed by the behaviour of cement paste characteristics in the transition zone.

The attractive forces between the cement paste and aggregate are in principle similar to those existing within the paste, and chemical reactions between them can strengthen the interfacial bond. The large difference by a factor of ten, between the compressive strength and tensile strength of cement concrete arises from the different binding forces involved and suggests that there is no extensive bridging or welding together of the crystallites. This probably involves a distinction between inter and intra-particle forces.

Since low porosity and well developed hydration products with homogeneous microstructure are primary requirements for high strength and low permeability, the water/cement ratio of the cement paste including that of the paste in the vicinity of coarse aggregate particles, must be kept as low as possible and uniformly equal with the fully dispersed state of cement particles in water. The knowledge of interfacial transition zone closely relates to the factors that are responsible for durability problems of concrete.

Porosity, Pore size distribution, Permeability and Ionic diffusion:

The consensus today is that the performance function requires data on the following aspects:

porosity and pore size distribution,
permeability and
ionic diffusion.

The performance index Pi should express the durability of the material for a particular environment and for a designed life. Different values of Pis will be obtained by weighting the influence of the dependent variables in such an index equation, according to the requirement for which the concrete is needed.

The traditional classification considers two classes of pores,

Gel pores associated with the formation of the hydration products, which is the intrinsic porosity, while,
Capillary pores are considered to be the remnants of water-filled space.

Micropores and smaller micropores are considered to form the intrinsic porosity and bigger meso and macropores make up the capillary pore system.

Both capillary pore volume and pore size decrease significantly as hydration proceeds or as W/C ratio is reduced.

In well hydrated, low W/C ratio pastes, the capillary pores may range from10 to 50 nm; in the high W/C ratio pastes, at early ages of hydration, the capillary pores may be as large as 300 to 500 nm.

It has been suggested that the pore size distribution, not the total capillary porosity, is a better criterion for evaluating the characteristics of hydrated cement pastes. Capillary pores larger than 50 nm, referred to as macro-pores, are assumed to be detrimental to the strength and impermeability, while voids smaller than 50 nm, referred to as micro-pores, are assumed to be more important to drying shrinkage and creep.

The Mercury Intrusion Porosimetry technique can be routinely used to measure pore size distributions in concrete or cement-paste. Pore size is related by the equation P=2r Cos Theta/R where r is the surface tension of Mercury, & Theta is the contact angle & R is the pore radius. It is the pore size distribution that actually controls the strength, permeability and volume changes in a hardened cement paste, and not the total porosity.

The classification of water held in pores of hydrated cement paste is based on the degree of difficulty or ease with which is can be removed and the dividing line between different states of water in paste is not rigid. The states of water are:

a) Capillary water present in voids larger than about 50 nm, which is free water and can be easily removed, and the water held in small capillaries (5 to 50nm) which on removal may cause shrinkage.

b) Absorbed water, which is close to the solid surface, present up to six molecular layers and is physically held by hydrogen bonding. The loss of this water can cause drying shrinkage of hydrated cement paste at about 30% RH.

c) Interlayer water, which is associated with the C-S-H structure. This water is lost below 11% RH & the C-S-H structure shrinks considerably when inner-layer water is lost.

d) Chemically combined water is the integral part of the structure of various cement hydration products. This can get lost when the hydrates decompose on heating.

Relevant Transport Mechanisms that influence Durability of Concrete

Diffusion of Water and Gases through empty pores, micro-cracks, & interfaces.

Diffusion of ions or solvation of gases in pore solutions.

Permeation of Water or Aqueous solutions through
empty /non-saturated pores.

Capillary suction of Water or aqueous solutions under pressure.

The Durability of Concrete is principally related to the ability of Water (with or without aggressive ions), Oxygen and Carbon Dioxide to penetrate Concrete Pore Structure.

Pore Size Classification (guidance scale)

-	Gel	Capillary	Air	Voids
Pore diameter Scale (in Nanometers)	2.5	20	50	10,000
	Micro	Meso	Macro	Voids

The Gel pores are associated with the formation of hydration products of Calcium Silicate Gel, which is the intrinsic porosity, while the Capillary pores are considered to be the remnants of water filled space. Both capillary pore volume and pore size decrease significantly as hydration proceeds or as W /C ratio is reduced. It is therefore now universally recognized that permeability characteristics of concrete play a dominant role in the durability of concrete than its compressive strength.

Epilogue :

The essence of making good concrete basically depends on understanding the important aspects of the process of concrete forming in its fresh and hardened states discussed in this article.

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Conservation of Heritage Buildings

Neelkanth D. Joshi

India's ar chitectural heritage constitutes a unique legacy of civilization, which embodies rich values of enduring relevance to contemporary Indian society. Conserving the architectural heritage therefore ensures survival of country' svery character that includes economical , cultural & the environmentally developed status of the society in a globalizing environment , within which it was originally evolved and therefore it has significant historic value. For example we have in India Mogul her itage, Buddhist heritage, Hindu temples, Jain temples, Christian churches, other monumental structures etc.

Most of the heritage buildings are like old people vulnerable to all sorts of dieses. Therefore in order to tackle the problem of conservation of heritage structures, one must under stand the causes of decay of common building materials such as brick, stone, mortar and timber which were generally used in the construction of heritage structures.

While narrating common causes of decay one must understand that in reality the causes of decay are complex and there may be two or three operating simultaneously. The main causes are structural issues, climatic causes, botanical and biological causes, action of insects and animals, atmospheric pollution, poor construction, inappropriate repair and negligence.

Climatic Causes -

• Sunlight - (Fig. 1.)

Ultra Violate light is particularly damaging to organic materials such as wood, textiles, pigments etc and it causes colors to fade and sur face to become brittle.

• Thermal Expansion -

Building materials expand when heated and contract when cooled. As a consequence stresses can build up between the individual materials and the building as a whole. The seasonal temperatures and the amount of sun, wind and rainfalling directly on to different parts of a structure contribute to overall thermal movement .

• Moisture -

Faulty disposal of rain water is the most frequent cause of deterioration in ancient masonry. Rain water washing against the surface of a s ructure will gradually wear it away. The mortar and porous masonry are particularly vulnerable. Rainwater penetration into the individual materials of the structure causes more damage through salt crystallization, continual wetting and drying and the action of frost and ice.

• Wind - (Fig. 2.)

Wind can exert a strong directional force. The exposed side of the structure can be subjected to pushing action wh le the protected side can exper ience suction and the towering structures deflect under wind pressure. Wind exacerbates the general external erosion of most building materials. Roof coverings can belifted up in high wind. Hard grit particles can be driven into soft stone and brick pock ets, boring holes into them by act ion of the wind rotat ing the par t icles or scouring their surfaces.

Fig. 1. Damage To Wood Caused By The Sun

Fig. 2. Damaged Stonework Caused By Combination Of Factors - Dust Particle Erosion, Soft Or Poor Quality Stone, Heat & Wind

Settlement Of Foundations -

1. Subsidence or Settlement (due to consolidation or collapse of the soils below the foundations).
2. Shrink -Swell effects (resulting from the wetting or drying of clayey soils that causes the clay to shrink when dried or swell when wetted up. Leaking drains or trees can contribute to this effect).
3. Ground Instability (due to slope movement).
4. Bearing Capacity Failure (due to inadequate strength in the foundation soils).
5. Liquefaction (of loose sands induced by earthquakes).

Fig. 3. Failure Of Structure Due To Settlement In Foundation

Corrosion Of Structural Steel –

Corrossion of steel occurs due to oxidation and it results in to loss of cross section, strength and ductility.

Fig. 4. Corrosion Of Structural Steel

Botanical –

Creeping plants can damage masonry by driving bullet -headed root into crumbling masonry causing disintegrat ion of the material . If forcibly removed it can pull off a weak surface of brickwork or plaster . The presence of plants growing in a wall is usually in indication of decayed mortar and excess moisture.

Fig. 5. Ivy Growing On Historic Brickwork

Fig. 6. Daisies Growing In An Area Of Damaged Mortar On A Historic Wall

Large plants or shrubs growing at the base of walls can trap moisture & their roots can damage the structure. Trees near buildings can undermine their foundations & cause ground heave. In clay soils trees can with draw ground moisture causing the surrounding soil to shrink , thus causing movement of the foundation and subsequent cracking of walls.

Biological –

Bacteria, lichens produce acids which react chemically with the building materials. Algae, moss and lichens produce humus in which larger and more damaging plants can grow. Fungi, mildew, moulds and yeasts do not need sunlight for growth. Wood is particularly at risk from dry and wet rot fungus. Fungicides and weed killers can damage the building materials.

Fig. 7. Moss Damages Roof Due To Its Weight, Water Retention & Lifting Of Tiles

fig. 8. Fungus Attack Causing Brown Rote Of The Roof Rafter

Insects –

Insects like woodworm, termite etc at tack organic materials such as wood. Masonry bees burrow in soft stone, weak brick s and crumbling mor tar joints.

Fig. 9. Ivy And Masonry Bee Damage The Historic Brickwork

Fig. 10. Damage To A Historic Wall Caused By Masonry Bees, An Inappropriate Pointing Style And Hard Cement Mortar

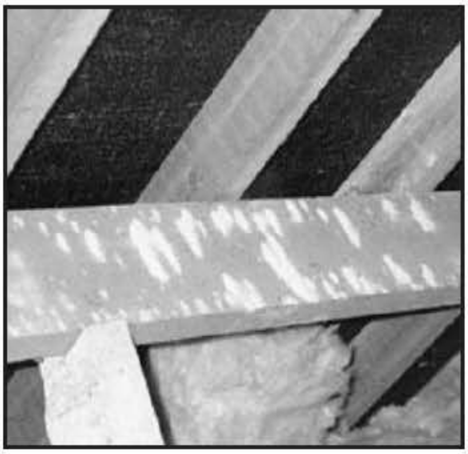

Fig. 11. Woodworm Boreholes

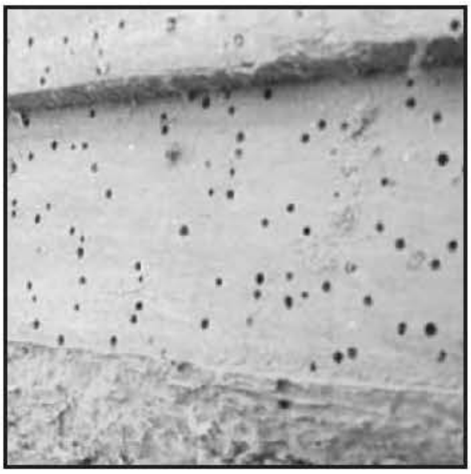

Fig. 12. Woodworm Dust

Birds & Animals –
Bird droppings can be highly corrosive to building materials and a health hazards to people.

Rats and mice can gain access to the building through the smallest holes. They are excellent climbers therefore they can enter anywhere. The rats can burrow to a depth of 750mm and dig long distances horizontally if the soil is loose. They can burrow into clay and thatched roofs.

Fig. 13. Bird Droppings - Heavily Soiled Stonework

Atmospheric Pollution –
Natural weathering causes stone to deteriorate over many thousands of years and bricks over several hundred years. This process is accelerated by pollutants released into the atmosphere such as oxides, carbon dioxide, nitrogen, sulphates, chlorides etc, combined with moisture in atmosphere produce a corrosive acidic mixtures.

Fig. 14. Deterioration Of Brick Masonry

Fig. 15. Deterioration Of Stone Masonry

The direct contact with wet stone of pollutant particles can cause severe acid deposition of ten more corrosive than acid rain and can also at tack shel tered areas. They can attack stone, bricks, roofing tiles, mortars, renders, cement , concrete, ferrous metals and non ferrous metals.

Inappropriate Repairs –
Using modern cement mortar to repointold walls, chemically injected damp proof courses, application of water repellent covering to exterior walls and renders, use of materials having inconsistent strength and modulus of elasticity compared to existing members.

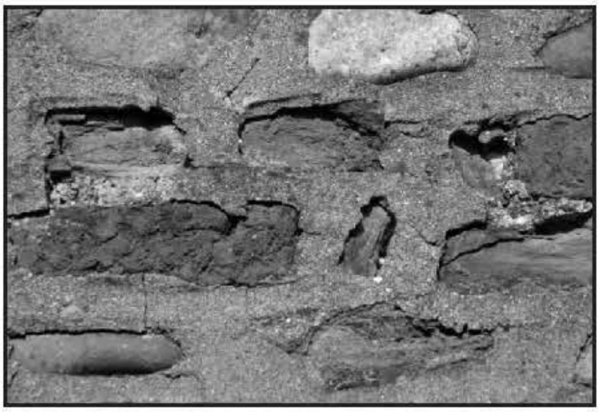

Fig. 16. Spalling Of Stone In A Historic Wall Due To The Inappropriate Use Of Hard Cement Mortar

Ear thquakes & Fi res –
Earthquakes can cause severe damage and even total destruction depending upon the configurat ion of the structure, its distance f rom the epicenter , intensity of the earthquake and also on the founding soil strata present below the structure.

Fig. 17. Earthquake Affected Brick Masonry Structure

Fig. 18. Earthquake Affected Stone Masonry Structure

Depending upon the intensity and duration of fire the structures can damaged.

Negligence –
Block ed rainwater goods, broken grills and plants growing in gutters and walls, Encourages moisture to penet rate the fabric, slipped and missing roofingtiles, Rusting metal windows, Exposed woodwork , Algae and fungalgrowths, Excessive moisture inside the building etc occurred due to negligence in maintenance and cleanliness.

After carefully studying all the above aspects one should decide on the selection of materials and process of rectification of the damaged portions to be used for conservation of the heritage structure so that the originality of the structure is preferably maintained.

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