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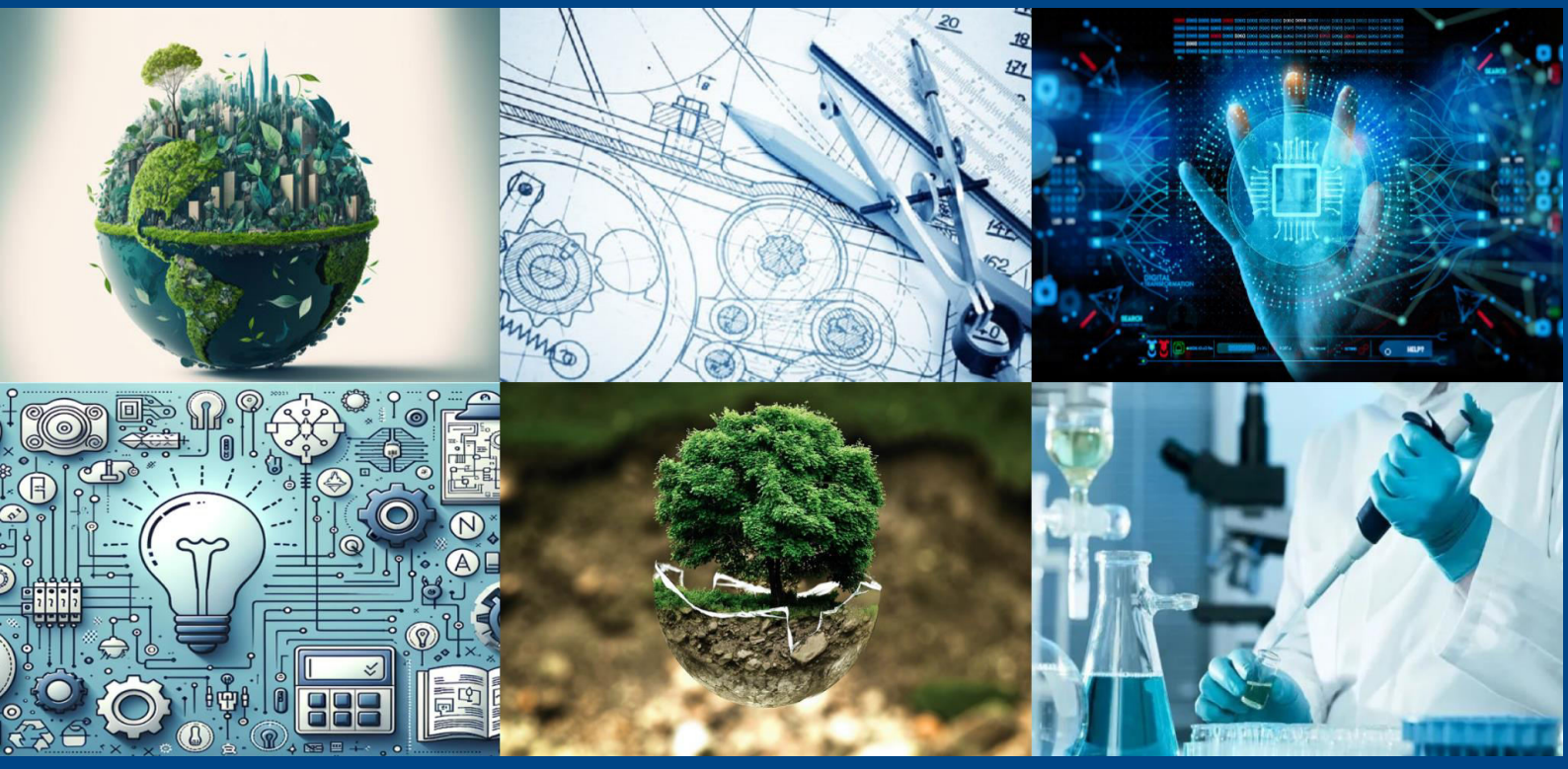

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Study of Structural Failure and Remedial Measures

Dr. N. S. Raman, Pragati Joseph

Assistant Professor, Dept. of Civil Engineering, Guru Nanak Institute of Technology, Nagpur, India

PG Student, Dept. of Civil Engineering, Guru Nanak Institute of Technology, Nagpur, India

ABSTRACT: India is a developing country and many projects are being implemented. Some of the projects involve construction of buildings. Nevertheless, some of the buildings are poorly constructed and maintained. One of the components that need attention is concrete. The concrete structure needs to be inspected and maintained regularly. Poor maintenance of concrete components will lead to the buildings being rendered not fit for occupancy. The main objectives of this study are to determine the types of concrete defect, the factors that cause concrete defects, the method of repairs and the problems faced by the Public Work Department (PWD) in carrying out the maintenance work. The study is carried out on government buildings in Nagpur. The data are collected through questionnaire and also from the records of the PWD. The data is analyzed by using average mean index. From the study, it was found that the main types of concrete defects are spalling and delamination. The factors that cause the defects are inefficient maintenance and poor construction method. The method of concrete repairs that are adapted by PWD are patching and sealing.

I. INTRODUCTION

After almost 78 years of independence, India is going into a new era of globalization, unleashing its potential and competition worldwide. Both Centre and state government worked hand in hand to make full utilization of the country's source and expertise in expanding the infrastructure in India. As the technology advances and changes, the need of more infrastructures will be more apparent. Infrastructure includes buildings, roads, bridges, utilities, and water supply, and sewerage system, mechanical and electrical systems. All of these infrastructures are important because it helps civilians to be able to live in a more systematic and ease environment. It helps to save cost, travelling time and providing facilities that will make life easier.

Many of these infrastructures will need proper maintenance to extend the lifespan besides promoting safety and reliability to the public. Building in particular are important structures and are a main concern of the government to make sure it is maintained regularly to prevent it from deteriorating and eventually could pose as a threat to the public. Poor maintenance might result in structural failure and wastage in money. For example, 5 roof leakages were spotted on Jan 2022 at the MLA hostel building in Nagpur. After inspection, it is found that the leakage was caused by cracks and seepage of water through the concrete roof. There was also no sign of maintenance done. Restoration and renovation work of MLA hostel building in Nagpur was previously done in 2019 by public work Circle. Although PWC had carried out a lot of repairs but there was reoccurring damage due to absence of maintenance. Once of the major components of building that needed attention is concrete defects. Defects in concrete, if not repaired, will eventually lead to major maintenance. Failure to provide necessary maintenance will cause more expensive repairs or replacement of otherwise useful structure. Besides that, any negligence in any of the phases of its maintenance would lead to its deterioration and ultimately failure to perform its intended function. Therefore, a proper and systematic maintenance management is required to reduce possible occurrence of disaster may cause life injury due to structural failure.

II. LITERATURE REVIEW

2.1 Engineering Encyclopaedia, Retrieved November, (2014), Structural defect means any defect in a structural element of a building that is attributable to defective design, defective or faulty workmanship or defective material and sometimes any combination of these. Building structure includes earth retaining walls, columns, beams and flat slabs. (Engineering Encyclopaedia, Retrieved November, 2014) According to the (Engineering Encyclopaedia, Retrieved November, 2014) structural defect can be categorized as cracks in foundations (Substructure), cracks in floor or slabs (superstructure), and cracks in walls (superstructure). These defects can be caused by improper soil analysis, inappropriate site selection, and the use of defective materials. Most of the structural problem can be avoided by

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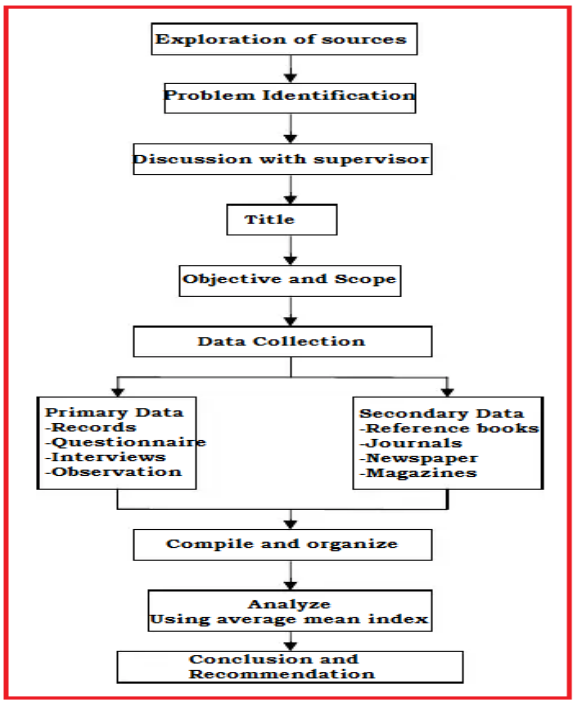
implying the exact and detail of the design and planning. Structural defects in a building can occur over time due to deterioration, wear and tear, overloading, and poor maintenance, cracks, and deflection.

2.2 Engineering Encyclopedia, Retrieved November, 2014, Non-structural defect in a residential building is described as a defect in a non-structural element of the building as a result of defective residential building work and also non-structural defect includes defect in brick work, dampness in old structures, and defects in plaster works.

2.3 Calvin "Cal" E. Beyer, 2011, Improper design Poor workmanship that leads to poor finishing quality, Improper means or methods of installation, Improper or poor quality of the materials, Defective material or poor material performance, Missing or inadequate protection from weather or environmental condition in the construction site and Soil subsidence, movement and settlement,

III. METHODOLOGY



IV. CASE STUDY

4.1 Introduction

Many developments of facilities and infrastructure are set up to improve the quality of life of residents in Nagpur. In line with that, many new buildings are being built as well as maintain in gold ones. Public Work Department (PWD) is in charge of maintaining government buildings throughout the districts in Maharashtra. Owners of government buildings are considered as clients in whom they are also partly responsible in conducting maintenance upon buildings with the supervision of PWD.

4.1 Maintenance System

Building maintenance upon government buildings should be conducted annually. Upon request from clients, Public Work Department (PWD) personnel will conduct inspection. PWD from the related district will send request and visual pictures of the defects to PWD Headquarters. Then, PWD lab department will be informed to conduct investigation.

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PWD team which consists of engineers and technician will go to the site and do visual inspection. Recordings of defects and its severity will be reported. Meanwhile Schmidt Hammer test will be conducted to determine the structural integrity of the concrete structure. More detailed and close-up photographs are taken. The engineer will then prepare a report which consists of findings including defect, test results, comment and recommendation.

Structural Department will receive this report and do assessment on the structural integrity of the building. After full validation by both lab department and structure department, recommendations will be sent back to District PWD and thereafter to the clients. Clients then will decide whether or not they will conduct maintenance and also by whom. If the client agrees to conduct repair work, PWD Headquarter will be informed. Elected contractor will conduct the maintenance work but with the supervision of PWD superintending officer (S.O). After all repair work is completed, a joint checking between PWD, contractor and client will be done.

4.3 Problems Faced by Public Work Department (PWD)

There are various problems faced by PWD in building maintenance. The responsibilities of making sure the building is safe for occupancy lies in the hand of both clients and PWD. However, the building maintenance culture is still not efficient enough. Clients do not usually conduct yearly maintenance. They will only see the need to inspect and maintain the building when there are serious defects and reports of major failure in other buildings. Meanwhile PWD faces challenges in the delay of maintenance procedure.

In Nagpur, the problem defective concrete is still prominent in some government buildings. According to several cases from previous reports, the use of dusty sand in concrete mix in which it is widely used as fine aggregate for construction in 1980's have further aggravated the problem of steel reinforcement corrosion in buildings. The main factor is poor treatment and site workmanship that has elevated the problem.

The maintenance of these buildings can be tedious and could eventually lead to major failure. For most concrete defect, patching is the most common repair technique that is adapted. Mortar patching will be used to repair horizontal repairs. Meanwhile for overhead and vertical repairs will use free flow cementitious grout and also patch repair mortar.

However, some defects have reoccurred even though maintenance has been done. This can be due to many factors. Insufficient previous maintenance such as plastering of spalling concrete and others usually causes the problem to reoccur. This eventually led to more repetitive repairs.

V. RESULT

Table 1. Types of Defect that Occur in Government Building

Sr. No.	Types of Defect	Number of Respondents					Min. Index	Rank
		1	2	3	4	5		
1	Longitudinal Crack	3	2	12	1	2	2.87	4
2	Transverse Crack	3	4	13	0	0	2.52	6
3	Shear Crack	3	10	6	1	0	2.30	8
4	Plastic Shrinkage Crack	5	2	5	9	1	3.00	4
5	Plastic Settlement Crack	3	5	10	2	0	2.55	6
6	Crazing Map Crack	5	11	4	1	0	2.00	8
7	Spalling	2	0	9	9	1	3.45	2
8	Delamination	1	2	8	9	0	3.25	2
9	Honeycombing	6	11	3	1	0	1.92	11
10	Scaling	1	6	11	1	0	2.67	5
11	Popouts	4	13	3	0	0	1.99	11

1 – Least frequent, 2 – Less frequent, 3 – Average, 4 –Frequent, 5- Very frequent

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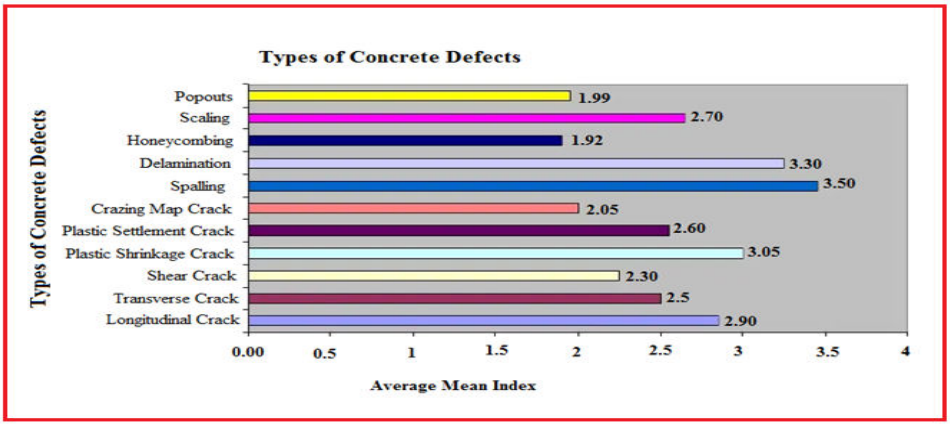

Fig. 1 Types of Concrete Defects that Occur in Government Building

Table 2. Factors that Causes Concrete Defect in Government Building

Sr. No.	Factors that Causes Concrete Defect	Number of Respondents					Min. Index	Rank
		1	2	3	4	5		
1	Construction Defect							
	Faulty Material	1	10	5	3	1	3.30	3
	Poor Construction Method	0	3	11	3	3	3.45	2
	Deficiency in quality Control	0	1	12	4	3	2.20	10
2	Faulty Design	1	14	5	0	0	2.25	9
3	Sulphate Deterioration	0	11	8	1	0	2.50	7
4	Alkali –aggregate reaction	0	4	13	2	1	3.00	4
5	Structural Over Loading	0	11	7	2	0	2.55	6
6	Inefficient Maintenance	0	3	3	9	5	3.80	1
7	Fire Damage	1	4	14	1	0	2.75	5
8	Seismic Movements	1	11	8	0	0	2.40	8

1 – Totally disagree, 2 – Disagree, 3 – Average, 4 – Agree, 5 – Totally agree

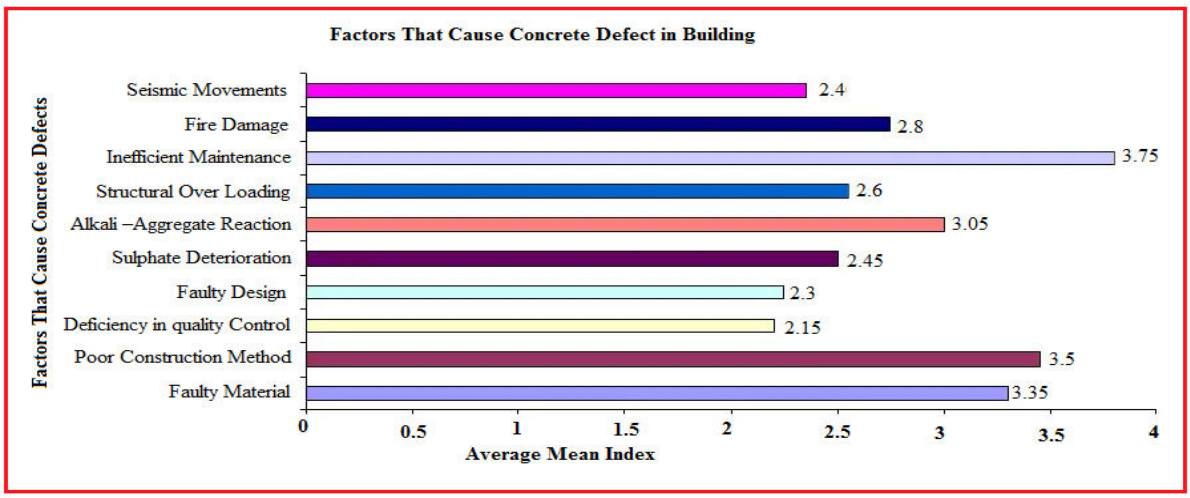

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Fig. 2 Factor's that Causes Concrete Defects in Government Buildings

Table 3 Method of Repair in Rectifying Concrete Defects

Sr. No.	Method of Repairs	Number of Respondents					Min. Index	Rank
		1	2	3	4	5		
1	Crack Injection	4	9	7	0	0	2.15	7
2	Patch Repairs	0	0	4	8	8	4.2	1
3	Sprayed Concrete	0	14	6	0	0	2.3	6
4	Grouting	3	11	3	1	2	2.4	5
5	Cathite Method	10	10	0	0	0	1.5	13
6	Cathodic Method	9	11	0	0	0	1.55	11
7	Decholorisation Method	7	12	1	0	0	1.7	10
8	Scaling	3	0	8	9	0	3.3	2
9	Dry Packing	4	12	13	1	0	2.05	8
10	Thin Bonded Resurfacing	4	1	6	9	0	3	4
11	Stitching	7	11	2	0	0	1.75	9
12	Caulking	10	9	1	0	0	1.55	12
13	Recasting	1	1	11	7	0	3.2	3

1 – Least frequent, 2 – Less frequent, 3 – Average, 4–Frequent, 5- Very frequent

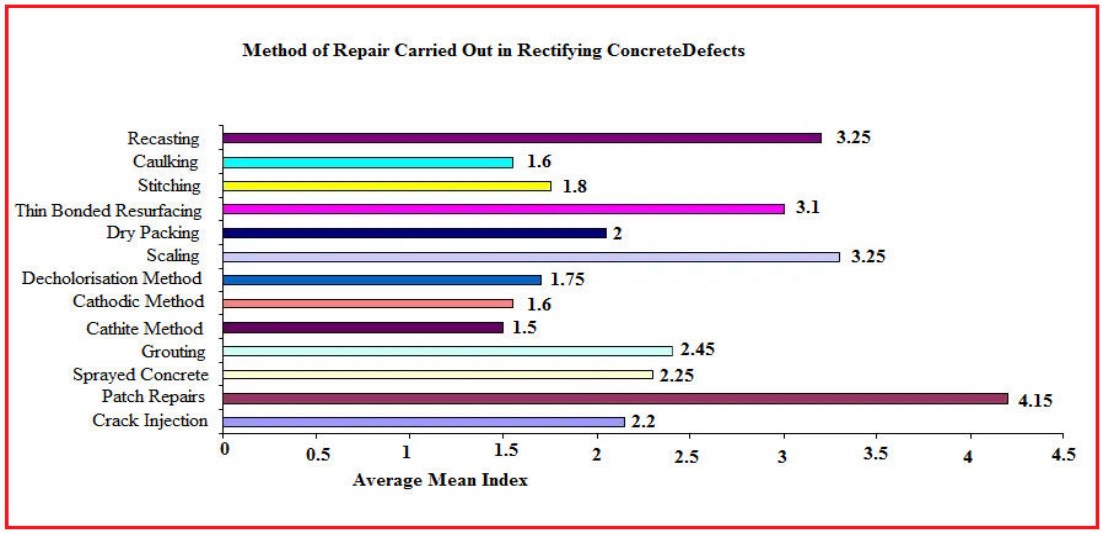

Fig. 3 Method of Repair in Rectifying Concrete Defects

Table 4 Factors Affecting Choice of Repair

Sr. No.	Factor affecting choice of Repairs	Number of Respondents					Min. Index
		1	2	3	4	5	
1	Severity of Defects	0	3	4	9	0	3.7
2	Time needed to execute the repair work	0	2	10	6	2	3.4
3	Repair Cost (Material & Labour)	0	0	5	12	3	3.9
4	Total Manpower Available to conduct work						3.1

1–Totally disagree, 2– Disagree, 3– Average, 4– Agree, 5– Totally agree

Meanwhile figure 4.6 shows the bar chart for the factors and its average mean index.

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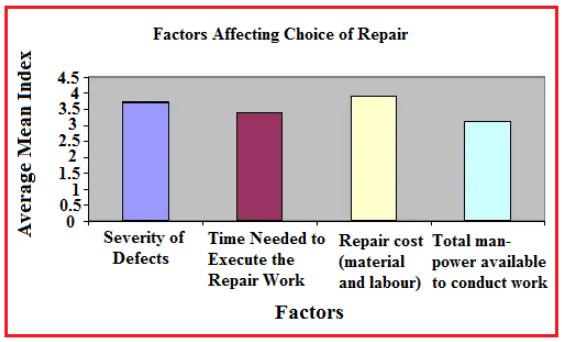

Figure 4 Factors Affecting Choice of Repair

Table 5 Common Problems Faced by PWD in Building Maintenance

Sr. No.	Common Problems in Building Maintenance	Number of Respondents					Min. Index	Rank
		1	2	3	4	5		
1	Insufficient Funding	0	2	11	7	2	3.25	3
2	Lack of Manpower	1	4	10	2	3	3.1	4
3	Personal lack of experience and Skill	0	8	10	1	1	2.75	8
4	Incomplete and out dated tool/Equipment	0	6	10	3	1	2.95	7
5	Delay in maintenance procedures	0	0	8	11	1	3.65	1
6	Less exposure to current technologies	0	4	12	4	0	3	6
7	Unavailability of previous record of building	0	6	7	6	1	3.1	5
8	Delay from Contractor	0	0	13	7	0	3.35	2

1– Totally disagree, 2– Disagree, 3 – Average, 4– Agree, 5– Totally agree

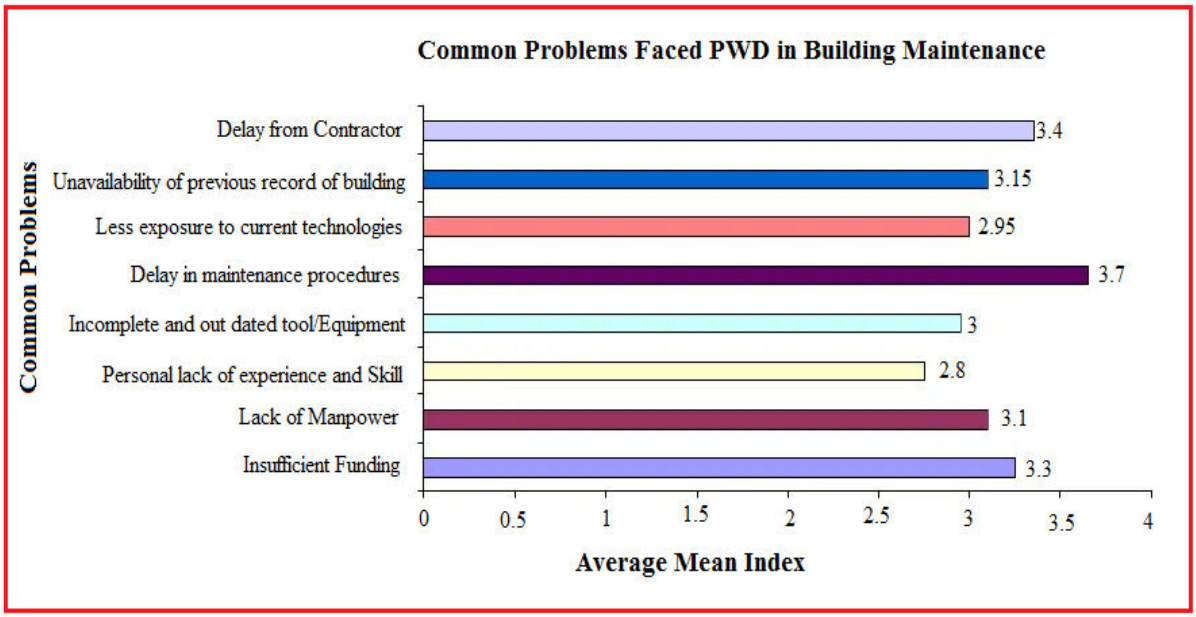

Fig. 5 Common Problems Faced by PWD in Building Maintenance

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VI. CONCLUSION & FUTURE SCOPE

6.1 Introduction

This research has been carried out to study the maintenance of concrete defects in government building. The scope includes maintenance done by Public Work Department (PWD) throughout Nagpur. The data collected consists of data from PWD past records, interviews, observation and questionnaires. From the analysis, the conclusion is made in relation to these following objectives:

v. To study the types of concrete defects that occurs in buildings
vi. To identify the factors that causes the concrete defects in buildings
vii. To identify the method of concrete repair carried out
viii. To identify the problems faced by PWD in maintenance of buildings

6.2 Conclusion

Conclusions are drawn based on the outcome of analysis from the previous chapter. All of the results are based on the questionnaire distributed. Besides that, past records and information that is collected from Public Work Department (PWD) are also used as comparison and added value to this whole research. From the study these are the conclusions that are described as follow.

6.2.1 Types of Concrete Defects that Occurs in Buildings

From the study, the types of concrete defects that occur in government buildings under the supervision of Public Work Department (PWD) can be determined. Below are the lists of defects from highest to lowest occurrence.

(i) Spalling
(ii) Delamination
(iii) Plastic Shrinkage Crack
(iv) Longitudinal crack
(v) Scaling
(vi) Plastic Settlement Crack
(vii) Transverse crack
(viii) Shear Crack
(ix) Crazing Map Crack
(x) Pop outs
(xi) Honeycombing

6.2.2 Factors that Causes the Concrete Defects in Buildings

From the study, the factors that cause concrete defects in buildings are identified and analyzed to obtain each average mean index. The conclusion are as below from highest to lowest mean index.

(i) Inefficient maintenance
(ii) Poor Construction Method
(iii) Faulty Materials
(iv) Alkali-aggregate Reaction
(v) Fire Damage
(vi) Structural Overloading
(vii) Sulphate Deterioration

6.2.3 Method of Concrete Repair Carried Out

From the study, the method of repair adopted by PWD can be identified. Different types of method apply to different type of defects. These are the method of concrete repair that are rated from highest to lowest mean index.

(i) Patch Repairs
(ii) Sealing
(iii) Recasting
(iv) Thin Bonded Resurfacing
(v) Grouting
(vi) Sprayed Concrete
(vii) Crack Injection

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(viii) Dry Packing
(ix) Stitching
(x) Decholorisation Method
(xi) Cathodic Method
(xii) Caulking
(xiii) Cathite Method

6.2.4 Problems faced by PWD in Maintenance of Buildings

From the study, the most common problems faced by PWD are identified based on the replies of respondents. The ratings are as below from highest to lowest average mean index.
(i) Delay in maintenance procedures
(ii) Delay from contractor
(iii) Insufficient Funding
(iv) Lack of Manpower
(v) Unavailability of previous records of building
(vi) Less exposure to current technologies
(vii) Incomplete and outdated tools/equipment
(viii) Personnel lack of experience and skills

6.3 Recommendation

Based on the study, these are a few recommendations that can be made to improve the maintenance done by PWD.
(i) There should be proper documentation of building maintenance records by PWD. A system database can provide the faster and easier access to information rather searching manual documentation.
(ii) Inspection and supervision on government buildings should be stricter as regular maintenance can reduce the possibility of structural failure that is more expensive and time consuming to rectify.
(iii) Personnel should undergo more training to gain more exposure on current technologies and techniques.

6.4 Recommendation for Further Study

From this study, a few recommendations are made for further study. There are as listed below:
(i) Detailed study on building maintenance procurement
(ii) To study the selection of material and repair technique in maintenance of concrete defect
(iii) To study the relationship between cost and defects in buildings.
(iv) To study the difference of building maintenance works done by PWD and by contractor
(v) To study the selection of contractor by PWD to conduct works
(vi) To study the implementation of information system in building maintenance

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