TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

PUBLIC WORKS DEPARTMENT
GOVERNMENT OF TAMILNADU
2018

TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

COMMISIONERATE
OF MUNICIPAL ADMINISTRATION
& DIRECTORATE OF TOWN PANCHAYAT

RURAL DEVELOPMENT & PANCHAYAT
RAJ DEPARTMENT

TAMILNADU
HOUSING BOARD

**PUBLIC
WORKS DEPARTMENT**

GREATER CHENNAI
CORPORATION

TAMILNADU SLUM
CLEARANCE BOARD

TAMIL NADU ADI DRAVIDAR
HOUSING AND DEVELOPMENT
CORPORATION

TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

First Edition: 2018

DISCLAIMER

The data, Thumb rules, Material Testing methodologies etc., illustrated in this Technical Hand Book are with a view to serve the field engineers for rapid checking of various aspects involved in building construction. The ideologies briefed in the text should not be conceived as a complete replacement for the actual engineering Design Calculations, Streamlined Laboratory Testing of Materials, Execution Methods etc.,

All the guide lines, conceptuals and ready-reckoner tips offered in this publication have no legal bindings but are based on the vast experiences gained by those Engineers, expertise in the relevant fields. Best efforts have been attempted to bring this book ensuring update and precise. Readers are at liberty to obtain the concurrence of their respective Departmental Heads /Chiefs and to implement their concepts, methodologies, ideologies etc.,

COMPILED BY PWD COMMITTEE

Er. S. MANOHAR, B.E., M.B.A., Engineer-in-Chief (Buildings) - PWD

Er.K.P. Sathyamurthy, B.E., M.C.A, Deputy Chief Engineer – PWD

Er. C. Kalyanasundaram, M.E., M.I.E., Executive Engineer – PWD

For Government Departments use only

TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

FOREWORD

In this vast field of Civil Engineering, there might be more number of books and technical circulars on building construction. Generally it is not possible for any field engineers to go through various books at a particular time, comparing their merits and demerits and to select the most appropriate one for their purpose.

Further in various books and technical journals the subject matters are more theoretical and are presented in such a manner that the Field engineers involved in construction could not easily follow and employ them in the field.

In Civil Engineering Industry, in both the Government and private sectors there are many experts who are well-versed in their specialty and who are capable of calling out a hardest job easily because of their enriched technical and practical knowledge gained due to their experience and learning from senior engineers.

This hand book contains simple technical terms and references, which will make this book stand apart from others.

This "Technical Hand Book on Building Construction for Field Engineers" has been compiled to satisfy a demand for "Simple Practical Techniques" to be used in the field in building construction and will definitely benefit a large number of Field Engineers relieving their reluctance towards implementing various techniques to build a safe, serviceable and durable structure.

ER. S. MANOHAR, B.E., M.B.A.,
Engineer-in-Chief (Buildings) and
Chief Engineers (Buildings)
Public Works Department
Chennai-600 005

TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

PREFACE

Civil Engineers must change radically in their professional approach and should improve their inputs for serviceable and durable structures to earn due respect from the Government and the masses.

But the incident of collapse of the Cantilever Roof Structure of the Bus Stand located in Somanur hamlet of Karumathampatti Town Panchayat in Coimbatore District occurred on 7th September 2017 resulting in the death of 5 persons and injuries to 12 persons.

As a consequence to the above unfortunate incident, the Government of Tamil Nadu formed the One-Man- Committee and appointed **Thiru.Gagandeep Singh Bedi, I.A.S.,** Agricultural Production Commissioner & Principal Secretary to Government, vide G.O.Ms.No.760, Public (Law and Order-F) Department, Dated 11.09.2017, to inquire into the causes and circumstances leading to the above incident and suggested remedial measures to prevent such occurrences in future.

Further based on the detailed discussions held with the technical officers of various Government departments, the committee has recommended some suggestions to avoid such un- toward incidents in future in the public buildings.

In one of its recommendations it is emphasized that departments constructing buildings for public usage should bring out Technical handbooks and made available to all the field engineers and the same be updated periodically in tune with the changing axiom.

Municipal Administration and Water Supply(TP.2) Department, vide G.O (D) No.248 dated 06-06-2018 as ordered by the Chief Secretary to Government, has constituted a technical committee as detailed below for preparing guide lines for construction, maintenance and demolition of buildings owned by Government.

Sl No.	Details of members of the Committee	Designation	Department/Head of Department
1	Engineer-in-Chief (Buildings) and Chief Engineer (Buildings), Chennai Region,Chennai	Head of the Committee	Public Works Department Chepauk,Chennai-5
2	Chief Engineer, Chennai	Member and convener	Commissionerate of Municipal Administration
3	Chief Engineer (Buildings), Chennai	Member	Greater Chennai Corporation
4	Superintending Engineer , Chennai	Member	Directorate of Town Panchayat
5	Chief Engineer, Chennai	Member	Tamil Nadu Housing Board
6	Chief Engineer, Chennai	Member	Tamil Nadu Slum Clearance Board
7	General Manager (Technical)	Member	Tamil Nadu Adi Dravidar Housing and Development Corporation(TAHDCO)

Considering all the above said instructions and keeping in view for a better quick reference in Technical related matters, efforts have been taken to publish this Technical Hand Book to be used as a guide to all civil engineers engaged in building construction.

The chapter packed with approximate methods and ready-reckoners in structural design helps to check or evolve size of structural members, rapidly.Cantilever Slabs are one of the weakest links in building and their Structural aspects are discussed along with a case study. Experience has indicated that damages occurred more due to errors in detailing than due to faulty calculations and hence a chapter on Reinforcement detailing is added with simplified practical sketches.

Guidelines for Earthquake Resistant Structures with Ductile Design and Detail explains the requirements for detailing of members of Reinforced Concrete structures.

A chapter on Rapid Testing Of Construction Materials at Site helps the Field Engineers to appreciate the quality of construction materials like Cement, Sand, Coarse aggregates etc., by mere visual observation and by conducting very simple site tests. Attached circulars issued by the Public works Department explaining the manufacturing process of good quality M-Sand and the methods of identifying, procuring and using them for construction purposes helps to understand the facts on M-sand and to get rid of the myths.

Quality Control Aspects consisting of Concrete – Cube Test, Acceptance Criteria as per IS 456-2000, Workability Of Concrete, Core Test for Concrete Structures, Non Destructive Tests (NDT) etc., are narrated clearly for Field Engineers.

In the chapter on CRACKS, Various types of Cracks, their important characteristics, causes and preventive measures are discussed with illustrative sketches.

Precautionary measures to be taken before monsoon rains, repair of rain water leakage in buildings etc., are discussed in the chapter Maintenance of Buildings.

In the chapter on Demolition of Buildings the structural audit of old structures, demolition methods etc., are briefly described.

The basic guidelines for fire and life safety measures are discussed.

Basic concepts of the new technology in Pre-fab technology is added explaining construction methodology etc.,

Guidlines for execution of various items of works like Formworks, Concreting, Masonry, Plastering etc., are presented.

It is fervently believed that the contents in this book will be more supportive and valuable to all the field engineers.

TECHNICAL COMMITTEE

CHAPTER - I

ENSURING THE ADEQAUCY OF RCC STRUCTURAL MEMBERS IN BUILDINGS

INTRODUCTION

Though the structural design is the duty of structural engineer it is essential for the Civil Engineers involved in building construction to acquire sufficient knowledge in structural aspects. Many times Field Engineers, come across variety of situations, where they themselves have to decide upon the size of the structural members. But they are not conversant with the techniques.

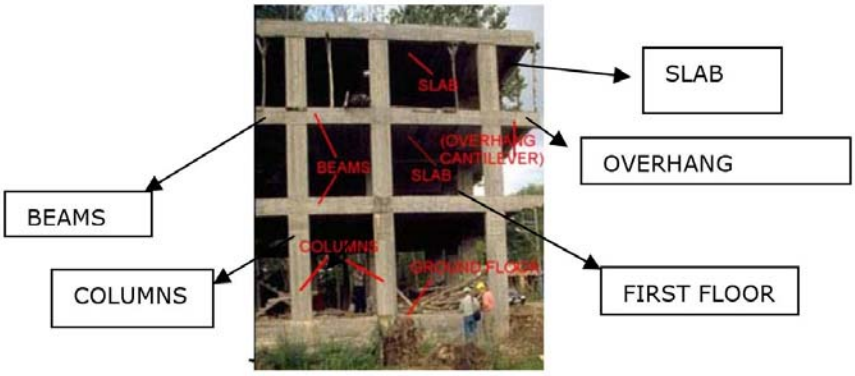
Hence this chapter packed with approximate methods and ready-reckoners will definitely relieve the reluctance towards structural design and will create confidence in their minds to check or evolve size of structural members and structural design as well, rapidly.

Not only Civil Engineers but even the Public layman can make use of these techniques while checking the size of structural members in buildings

When our neighbours / friends take us as an advisor to buy a Flat in an apartment under construction (or even completed) the adequacy of member sizes could easily be appraised on the spot itself knowing these techniques.

Architectural (flesh and skin)

Structural (Bones)



FUNCTIONS OF STRUCTURAL MEMBERS

In general, a building consists of basic structural elements like slabs, beams, columns and footings. These structural elements which are similar to bones in human body are covered by cosmetic elements like wall cladding, flooring tiles, plastering etc., like flesh and skin of human body. Bones are meant for strength whereas flesh and skin are to exhibit beauty.

1. SLABS:

Slabs serve as floor or roof by carrying the loads imposed on them.

2. BEAMS

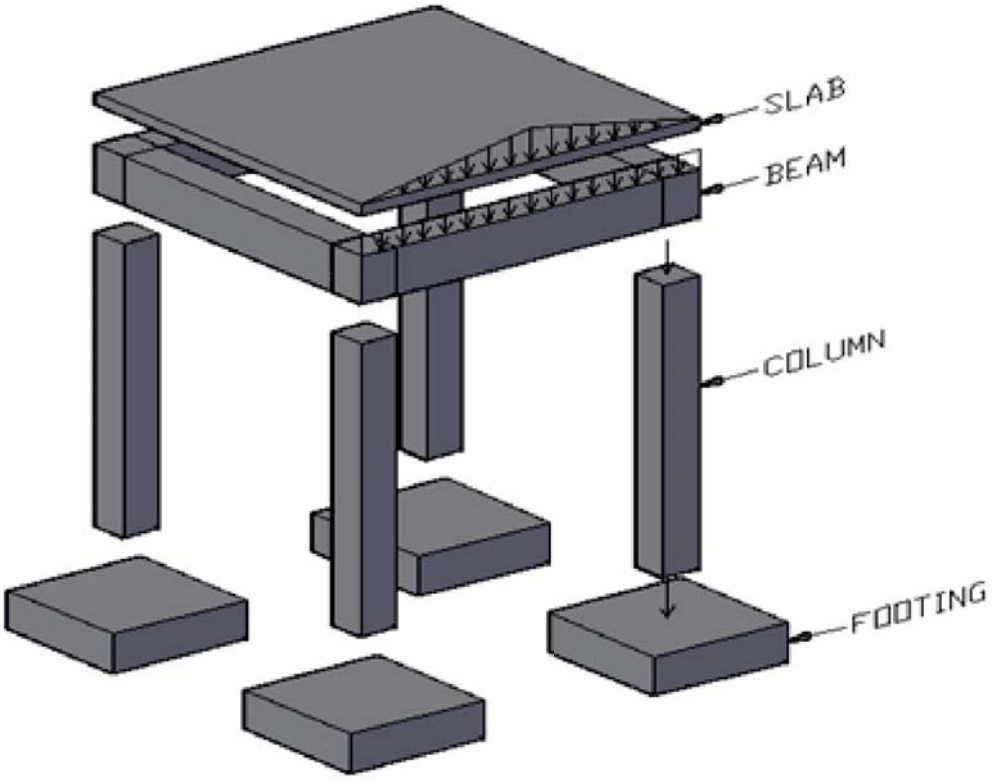
Beams carry the loads transmitted from slabs and walls.

3. COLUMNS

Columns carry the loads transmitted from beams and transmit them to the footings.

4. FOOTINGS

Footings distribute the loads transmitted from the columns into soil.



LOAD DISTRIBUTION

APPRAISAL OF SIZE OF VARIOUS STRUCTURAL MEMBERS

1. SLABS: How to calculate Thickness of slab?

(One way, Two way Slabs)

For one way and Two way slabs, Assume 1cm thick per 1 foot span

if, lx = 5m
Span of slab in feet = 5 x 3 = 15 feet.
Hence thickness to be provided = 15cm.

Span in metre	Thickness in "mm"
Up to 3.50 m	120 mm
3.60 to 4.0 m	130 mm
4.10 to 4.50m	140 mm
4.60 to 5.0 m	150 mm
5.10 to 6.0 m	180 mm

(Cantilever Slabs)

For Cantilever slabs

Thickness : Span /10

Span in metre	Thickness in "mm"
1.0 m	100 mm
1.20 m	120 mm
1.50 m	150 mm
1.80 m	180 mm
2.0 m	200mm

Slabs in a Typical Building

Typical Floor Plan of a Building

2. **BEAMS:**

EVOLVING SIZE OF BEAM

Concrete of Grade = M20

Steel = Fe415

Span = 6.0m

[7 (to) 8 cm depth per meter of span is assumed]

Depth of beam for 6.0m span =

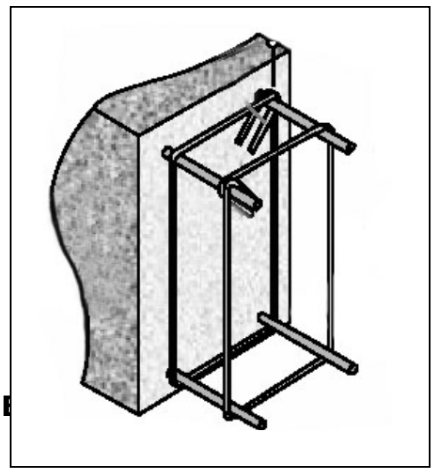
6.0 x 7 = 42cm

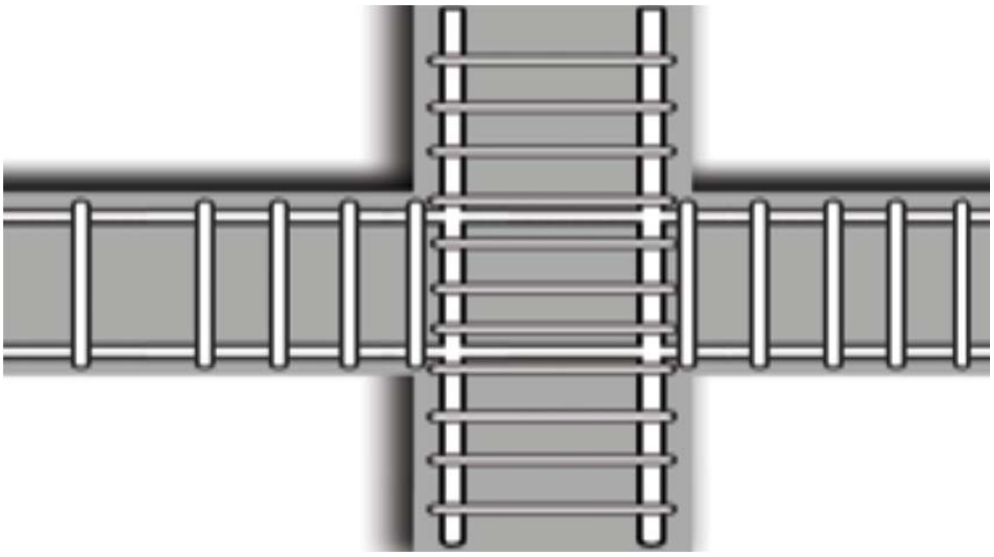
6.0 x 8 = 48cm

Hence adopt depth of Beam as 45 cm (i.e.,450 mm)

Assume size of Beam as

(300x450) / (230x450)





Typical Beam – Column Junction

3. COLUMNS

How to Judge COLUMN size ??

3.1 APPROXIMATE APPROACH FOR FINDING COLUMN FORCES

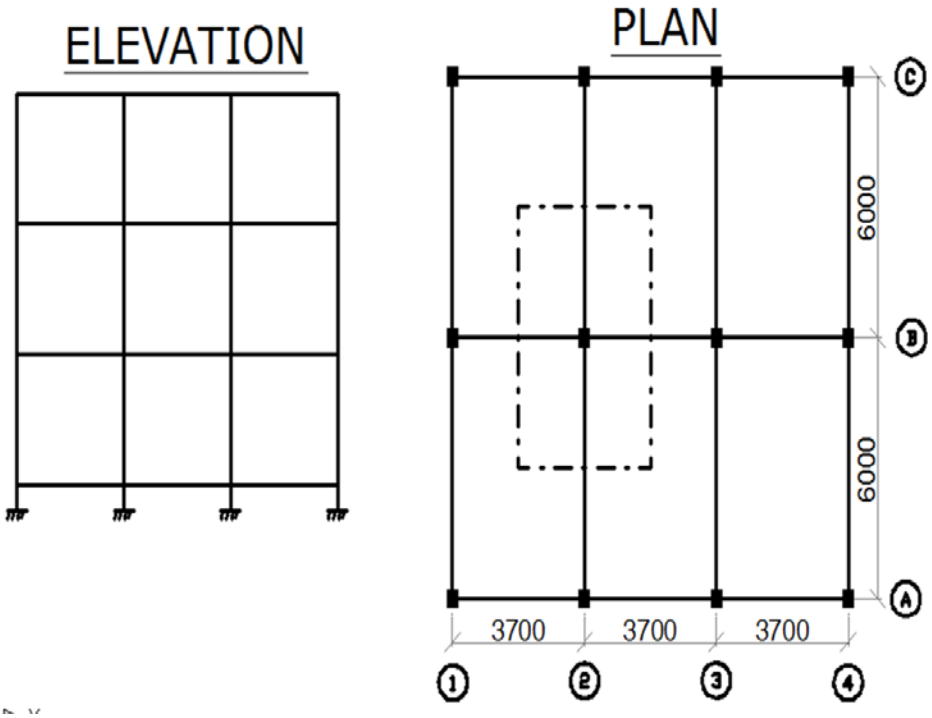


Table 1

COLUMN POSITION	LOAD IN KN/M^2		EXAMPLE
	RESIDENT BLDG.	OFFICE BLDG.	
INTERIOR	12	14	B2,B3
EDGE	17	19	A2,A3,C2,C3
CORNER	22	24	A1,A4,C1,C4

DESIGN OF COLUMN B2

Illustration

The buildng shown has three storeys.

i)CALCULATION OF LOAD ON COLUMN

Load influence area on column B2 (i.e.tributory area)

= (3.70/2 + 3.70/2) (6.0/2+ 6.0/2) = 22m²

Load on column B2 due to single storey

= 22.0 x 12 =264 KN

(Area)x (Coef. as per table-1 of previous page)

Total load on column B2 = 792 kN say **800 kN**

[Due to 3 storeys (264 x 3)]

ii) DESIGN OF COLUMN

Load on Column = 800 kN

Concrete grade = M20(say)

As per table-3 (next page), for 230 mm 450mm size,

If 1.40% of steel is provided,

It's load carrying capacity = 813 KN (>800 KN)

Hence ok

Steel area = (1.4/ 100) x 230x450=1449 mm²

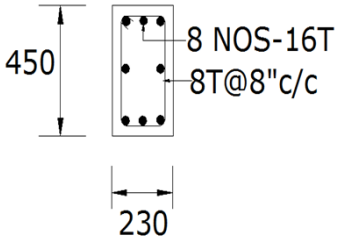
Hence provide 8 nos of 16 mm dia bars (ref. table-2 also)

Lateral ties (rings).

Provide 8 mm dia rings @ 8"c/c

Table 2 (Area of Bars)

Dia mm	Area Cm^2
12	1.13
16	2.01
20	3.14
25	4.91
32	8.04



C.S. OF COLUMN

Design of Column without Table in Hand

For M20 concrete & Fe 415 steel,

Load Carrying Capacity of Colmn with 2% reinft. = (0.90) Cross section Area of concrete in "cm²"

Therefore Load Carrying Capacity of (300x300mm) column with 2% reinft. =0.90x30x30 = 810 kN (>800kN)

Size of Column :300x300mm Hence Ok

Reinft. =2%=(2/100) x30x30 =18 cm2

Hence Provide (4Nos. - 20mmdia + 4Nos. - 16mm dia)

Table 1.1: Load Carrying Capacity of Column (1% to 2% reinft. is Generally Economical)																		M20	Fe415
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY																	
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.50	3.60	3.80	4.00
230	230	358	377	396	415	435	454	473	492	511	530	549	568	587	606	615	625	644	663
230	300	467	492	517	542	567	592	616	641	666	691	716	741	766	790	803	815	840	865
230	400	623	656	689	723	756	789	822	855	888	921	954	988	1021	1054	1070	1087	1120	1153
230	450	701	738	776	813	850	887	925	962	999	1036	1074	1111	1148	1186	1204	1223	1260	1297
230	500	779	820	862	903	945	986	1027	1069	1110	1152	1193	1234	1276	1317	1338	1359	1400	1441
230	600	935	984	1034	1084	1134	1183	1233	1283	1332	1382	1432	1481	1531	1581	1606	1630	1680	1730
230	750	1168	1231	1293	1355	1417	1479	1541	1603	1665	1727	1790	1852	1914	1976	2007	2038	2100	2162
300	300	610	642	674	707	739	772	804	836	869	901	934	966	998	1031	1047	1063	1096	1128
300	400	813	856	899	942	986	1029	1072	1115	1158	1202	1245	1288	1331	1375	1396	1418	1461	1504
300	450	914	963	1012	1060	1109	1157	1206	1255	1303	1352	1401	1449	1498	1546	1571	1595	1644	1692
300	500	1016	1070	1124	1178	1232	1286	1340	1394	1448	1502	1556	1610	1664	1718	1745	1772	1826	1880
300	600	1219	1284	1349	1414	1478	1543	1608	1673	1738	1803	1867	1932	1997	2062	2094	2127	2191	2256
300	750	1524	1605	1686	1767	1848	1929	2010	2091	2172	2253	2334	2415	2496	2577	2618	2658	2739	2820
300	900	1829	1926	2023	2121	2218	2315	2412	2509	2607	2704	2801	2898	2995	3093	3141	3190	3287	3384
400	400	1084	1141	1199	1257	1314	1372	1429	1487	1545	1602	1660	1717	1775	1833	1862	1890	1948	2006
400	500	1355	1427	1499	1571	1643	1715	1787	1859	1931	2003	2075	2147	2219	2291	2327	2363	2435	2507
400	600	1626	1712	1798	1885	1971	2058	2144	2231	2317	2403	2490	2576	2663	2749	2792	2835	2922	3008
400	700	1897	1997	2098	2199	2300	2401	2502	2602	2703	2804	2905	3006	3106	3207	3258	3308	3409	3510
400	800	2168	2283	2398	2513	2628	2744	2859	2974	3089	3205	3320	3435	3550	3665	3723	3781	3896	4011
450	450	1372	1445	1517	1590	1663	1736	1809	1882	1955	2028	2101	2174	2247	2320	2356	2392	2465	2538
450	600	1829	1926	2023	2121	2218	2315	2412	2509	2607	2704	2801	2898	2995	3093	3141	3190	3287	3384
450	750	2286	2408	2529	2651	2772	2894	3015	3137	3258	3380	3501	3623	3744	3866	3927	3987	4109	4230
450	900	2743	2889	3035	3181	3327	3472	3618	3764	3910	4056	4202	4347	4493	4639	4712	4785	4931	5077
600	600	2438	2568	2698	2827	2957	3087	3216	3346	3475	3605	3735	3864	3994	4124	4188	4253	4383	4512
600	750	3048	3210	3372	3534	3696	3858	4020	4182	4344	4506	4668	4830	4992	5155	5236	5317	5479	5641
600	900	3658	3852	4047	4241	4435	4630	4824	5019	5213	5408	5602	5797	5991	6185	6283	6380	6574	6769
600	1200	4877	5136	5395	5655	5914	6173	6432	6692	6951	7210	7469	7729	7988	8247	8377	8506	8766	9025

Tips - without Table in Hand: Load carrying capacity of Column = (0.90)xCross section Area in cm^2 (with 2% reinft.) ie.,30cmx40cm column (with 2.0% reinft.) can carry approximately 1080 kN. (M20 conc,Fe 415 Steel)

Table 1.2 : LOAD CARRYING CAPACITY OF COLUMNS("P"LOADS IN KN)																M20	Fe500
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY															
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
230	230	374	397	421	444	467	490	513	536	559	582	605	628	651	674	697	720	743
230	300	488	518	549	579	609	639	669	699	729	759	789	819	849	879	910	940	970
230	400	651	691	731	771	812	852	892	932	972	1012	1052	1092	1132	1173	1213	1253	1293
230	450	733	778	823	868	913	958	1003	1048	1094	1139	1184	1229	1274	1319	1364	1409	1455
230	500	814	864	914	964	1014	1065	1115	1165	1215	1265	1315	1365	1416	1466	1516	1566	1616
230	600	977	1037	1097	1157	1217	1278	1338	1398	1458	1518	1578	1639	1699	1759	1819	1879	1939
230	750	1221	1296	1371	1446	1522	1597	1672	1747	1823	1898	1973	2048	2123	2199	2274	2349	2424
300	300	637	676	715	755	794	833	872	912	951	990	1029	1069	1108	1147	1186	1226	1265
300	400	849	902	954	1006	1059	1111	1163	1216	1268	1320	1372	1425	1477	1529	1582	1634	1686
300	450	955	1014	1073	1132	1191	1250	1309	1367	1426	1485	1544	1603	1662	1721	1779	1838	1897
300	500	1062	1127	1192	1258	1323	1389	1454	1519	1585	1650	1716	1781	1846	1912	1977	2043	2108
300	600	1274	1352	1431	1509	1588	1666	1745	1823	1902	1980	2059	2137	2216	2294	2373	2451	2530
300	750	1592	1691	1789	1887	1985	2083	2181	2279	2377	2475	2573	2672	2770	2868	2966	3064	3162
300	900	1911	2029	2146	2264	2382	2499	2617	2735	2853	2970	3088	3206	3324	3441	3559	3677	3794
400	400	1132	1202	1272	1342	1411	1481	1551	1621	1690	1760	1830	1900	1969	2039	2109	2179	2249
400	500	1415	1503	1590	1677	1764	1851	1939	2026	2113	2200	2287	2375	2462	2549	2636	2723	2811
400	600	1699	1803	1908	2012	2117	2222	2326	2431	2536	2640	2745	2850	2954	3059	3164	3268	3373
400	700	1982	2104	2226	2348	2470	2592	2714	2836	2958	3080	3202	3325	3447	3569	3691	3813	3935
400	800	2265	2404	2544	2683	2823	2962	3102	3241	3381	3520	3660	3799	3939	4079	4218	4358	4497
450	450	1433	1521	1610	1698	1786	1875	1963	2051	2139	2228	2316	2404	2493	2581	2669	2758	2846
450	600	1911	2029	2146	2264	2382	2499	2617	2735	2853	2970	3088	3206	3324	3441	3559	3677	3794
450	750	2389	2536	2683	2830	2977	3124	3272	3419	3566	3713	3860	4007	4154	4302	4449	4596	4743
450	900	2866	3043	3219	3396	3573	3749	3926	4102	4279	4456	4632	4809	4985	5162	5338	5515	5692
600	600	2548	2705	2862	3019	3176	3333	3490	3647	3804	3960	4117	4274	4431	4588	4745	4902	5059
600	750	3185	3381	3577	3773	3970	4166	4362	4558	4754	4951	5147	5343	5539	5735	5932	6128	6324
600	900	3822	4057	4293	4528	4764	4999	5234	5470	5705	5941	6176	6412	6647	6882	7118	7353	7589
600	1200	5096	5410	5724	6037	6351	6665	6979	7293	7607	7921	8235	8549	8863	9177	9491	9804	10118

Table 1.3 : LOAD CARRYING CAPACITY OF COLUMNS("P"LOADS IN KN)																M25		Fe415
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY																
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
230	230	428	447	466	485	504	523	542	561	580	598	617	636	655	674	693	712	731
230	300	559	583	608	633	657	682	707	731	756	781	805	830	855	879	904	929	953
230	400	745	778	811	843	876	909	942	975	1008	1041	1074	1107	1139	1172	1205	1238	1271
230	450	838	875	912	949	986	1023	1060	1097	1134	1171	1208	1245	1282	1319	1356	1393	1430
230	500	931	972	1013	1054	1095	1137	1178	1219	1260	1301	1342	1383	1424	1465	1506	1548	1589
230	600	1117	1167	1216	1265	1315	1364	1413	1463	1512	1561	1610	1660	1709	1758	1808	1857	1906
230	750	1397	1458	1520	1582	1643	1705	1767	1828	1890	1951	2013	2075	2136	2198	2260	2321	2383
300	300	729	761	793	825	857	889	922	954	986	1018	1050	1082	1115	1147	1179	1211	1243
300	400	972	1014	1057	1100	1143	1186	1229	1272	1315	1358	1400	1443	1486	1529	1572	1615	1658
300	450	1093	1141	1189	1238	1286	1334	1382	1431	1479	1527	1575	1624	1672	1720	1768	1817	1865
300	500	1214	1268	1322	1375	1429	1482	1536	1590	1643	1697	1751	1804	1858	1911	1965	2019	2072
300	600	1457	1522	1586	1650	1715	1779	1843	1908	1972	2036	2101	2165	2229	2294	2358	2422	2487
300	750	1822	1902	1982	2063	2143	2224	2304	2385	2465	2545	2626	2706	2787	2867	2947	3028	3108
300	900	2186	2282	2379	2475	2572	2668	2765	2861	2958	3054	3151	3247	3344	3440	3537	3633	3730
400	400	1295	1353	1410	1467	1524	1581	1639	1696	1753	1810	1867	1924	1982	2039	2096	2153	2210
400	500	1619	1691	1762	1834	1905	1977	2048	2120	2191	2263	2334	2406	2477	2548	2620	2691	2763
400	600	1943	2029	2115	2200	2286	2372	2458	2544	2629	2715	2801	2887	2972	3058	3144	3230	3316
400	700	2267	2367	2467	2567	2667	2767	2867	2967	3068	3168	3268	3368	3468	3568	3668	3768	3868
400	800	2591	2705	2820	2934	3048	3163	3277	3391	3506	3620	3734	3849	3963	4078	4192	4306	4421
400	900	2915	3043	3172	3301	3429	3558	3687	3815	3944	4073	4201	4330	4459	4587	4716	4845	4973
450	450	1639	1712	1784	1857	1929	2001	2074	2146	2218	2291	2363	2436	2508	2580	2653	2725	2797
450	600	2186	2282	2379	2475	2572	2668	2765	2861	2958	3054	3151	3247	3344	3440	3537	3633	3730
450	750	2732	2853	2974	3094	3215	3336	3456	3577	3697	3818	3939	4059	4180	4301	4421	4542	4662
450	900	3279	3424	3568	3713	3858	4003	4147	4292	4437	4582	4726	4871	5016	5161	5305	5450	5595
600	600	2915	3043	3172	3301	3429	3558	3687	3815	3944	4073	4201	4330	4459	4587	4716	4845	4973
600	750	3643	3804	3965	4126	4287	4447	4608	4769	4930	5091	5252	5412	5573	5734	5895	6056	6217
600	900	4372	4565	4758	4951	5144	5337	5530	5723	5916	6109	6302	6495	6688	6881	7074	7267	7460

Table 1.4 : LOAD CARRYING CAPACITY OF COLUMNS("P"LOADS IN KN)																		M25	Fe500
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY																	
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	
230	230	374	397	421	444	467	490	513	536	559	582	605	628	651	674	697	720	743	
230	300	488	518	549	579	609	639	669	699	729	759	789	819	849	879	910	940	970	
230	400	651	691	731	771	812	852	892	932	972	1012	1052	1092	1132	1173	1213	1253	1293	
230	450	733	778	823	868	913	958	1003	1048	1094	1139	1184	1229	1274	1319	1364	1409	1455	
230	500	814	864	914	964	1014	1065	1115	1165	1215	1265	1315	1365	1416	1466	1516	1566	1616	
230	600	977	1037	1097	1157	1217	1278	1338	1398	1458	1518	1578	1639	1699	1759	1819	1879	1939	
230	750	1221	1296	1371	1446	1522	1597	1672	1747	1823	1898	1973	2048	2123	2199	2274	2349	2424	
300	300	637	676	715	755	794	833	872	912	951	990	1029	1069	1108	1147	1186	1226	1265	
300	400	849	902	954	1006	1059	1111	1163	1216	1268	1320	1372	1425	1477	1529	1582	1634	1686	
300	450	955	1014	1073	1132	1191	1250	1309	1367	1426	1485	1544	1603	1662	1721	1779	1838	1897	
300	500	1062	1127	1192	1258	1323	1389	1454	1519	1585	1650	1716	1781	1846	1912	1977	2043	2108	
300	600	1274	1352	1431	1509	1588	1666	1745	1823	1902	1980	2059	2137	2216	2294	2373	2451	2530	
300	750	1592	1691	1789	1887	1985	2083	2181	2279	2377	2475	2573	2672	2770	2868	2966	3064	3162	
300	900	1911	2029	2146	2264	2382	2499	2617	2735	2853	2970	3088	3206	3324	3441	3559	3677	3794	
400	400	1132	1202	1272	1342	1411	1481	1551	1621	1690	1760	1830	1900	1969	2039	2109	2179	2249	
400	500	1415	1503	1590	1677	1764	1851	1939	2026	2113	2200	2287	2375	2462	2549	2636	2723	2811	
400	600	1699	1803	1908	2012	2117	2222	2326	2431	2536	2640	2745	2850	2954	3059	3164	3268	3373	
400	700	1982	2104	2226	2348	2470	2592	2714	2836	2958	3080	3202	3325	3447	3569	3691	3813	3935	
400	800	2265	2404	2544	2683	2823	2962	3102	3241	3381	3520	3660	3799	3939	4079	4218	4358	4497	
400	900	2548	2705	2862	3019	3176	3333	3490	3647	3804	3960	4117	4274	4431	4588	4745	4902	5059	
450	450	1433	1521	1610	1698	1786	1875	1963	2051	2139	2228	2316	2404	2493	2581	2669	2758	2846	
450	600	1911	2029	2146	2264	2382	2499	2617	2735	2853	2970	3088	3206	3324	3441	3559	3677	3794	
450	750	2389	2536	2683	2830	2977	3124	3272	3419	3566	3713	3860	4007	4154	4302	4449	4596	4743	
450	900	2866	3043	3219	3396	3573	3749	3926	4102	4279	4456	4632	4809	4985	5162	5338	5515	5692	
600	600	2548	2705	2862	3019	3176	3333	3490	3647	3804	3960	4117	4274	4431	4588	4745	4902	5059	
600	750	3185	3381	3577	3773	3970	4166	4362	4558	4754	4951	5147	5343	5539	5735	5932	6128	6324	
600	900	3822	4057	4293	4528	4764	4999	5234	5470	5705	5941	6176	6412	6647	6882	7118	7353	7589	

Table 1.5: LOAD CARRYING CAPACITY OF COLUMNS("P"LOADS IN KN)																		M30	Fe415
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY																	
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	
230	230	498	517	536	555	573	592	611	630	648	667	686	705	723	742	761	780	799	
230	300	650	674	699	723	748	772	797	821	846	870	895	919	944	968	993	1017	1042	
230	400	867	899	932	964	997	1030	1062	1095	1128	1160	1193	1226	1258	1291	1323	1356	1389	
230	450	975	1012	1048	1085	1122	1158	1195	1232	1269	1305	1342	1379	1415	1452	1489	1526	1562	
230	500	1083	1124	1165	1206	1246	1287	1328	1369	1410	1450	1491	1532	1573	1614	1654	1695	1736	
230	600	1300	1349	1398	1447	1496	1545	1594	1642	1691	1740	1789	1838	1887	1936	1985	2034	2083	
230	750	1625	1686	1747	1808	1870	1931	1992	2053	2114	2175	2237	2298	2359	2420	2481	2543	2604	
300	300	848	880	912	943	975	1007	1039	1071	1103	1135	1167	1199	1231	1263	1295	1327	1359	
300	400	1130	1173	1215	1258	1301	1343	1386	1428	1471	1513	1556	1599	1641	1684	1726	1769	1811	
300	450	1272	1319	1367	1415	1463	1511	1559	1607	1655	1703	1750	1798	1846	1894	1942	1990	2038	
300	500	1413	1466	1519	1572	1626	1679	1732	1785	1839	1892	1945	1998	2051	2105	2158	2211	2264	
300	600	1695	1759	1823	1887	1951	2015	2079	2142	2206	2270	2334	2398	2462	2525	2589	2653	2717	
300	750	2119	2199	2279	2359	2439	2518	2598	2678	2758	2838	2917	2997	3077	3157	3237	3316	3396	
300	900	2543	2639	2735	2830	2926	3022	3118	3214	3309	3405	3501	3597	3692	3788	3884	3980	4076	
400	400	1507	1564	1621	1677	1734	1791	1848	1904	1961	2018	2075	2131	2188	2245	2302	2358	2415	
400	500	1884	1955	2026	2097	2168	2239	2309	2380	2451	2522	2593	2664	2735	2806	2877	2948	3019	
400	600	2261	2346	2431	2516	2601	2686	2771	2856	2942	3027	3112	3197	3282	3367	3452	3538	3623	
400	700	2637	2737	2836	2935	3035	3134	3233	3333	3432	3531	3631	3730	3829	3929	4028	4127	4227	
400	800	3014	3128	3241	3355	3468	3582	3695	3809	3922	4036	4149	4263	4376	4490	4603	4717	4830	
400	900	3391	3519	3646	3774	3902	4029	4157	4285	4412	4540	4668	4796	4923	5051	5179	5306	5434	
450	450	1907	1979	2051	2123	2195	2267	2338	2410	2482	2554	2626	2698	2769	2841	2913	2985	3057	
450	600	2543	2639	2735	2830	2926	3022	3118	3214	3309	3405	3501	3597	3692	3788	3884	3980	4076	
450	750	3179	3299	3418	3538	3658	3778	3897	4017	4137	4256	4376	4496	4616	4735	4855	4975	5094	
450	900	3815	3958	4102	4246	4389	4533	4677	4820	4964	5108	5251	5395	5539	5682	5826	5970	6113	
600	600	3391	3519	3646	3774	3902	4029	4157	4285	4412	4540	4668	4796	4923	5051	5179	5306	5434	
600	750	4239	4398	4558	4717	4877	5037	5196	5356	5516	5675	5835	5994	6154	6314	6473	6633	6793	
600	900	5086	5278	5469	5661	5852	6044	6236	6427	6619	6810	7002	7193	7385	7576	7768	7960	8151	

Table 1.6 : LOAD CARRYING CAPACITY OF COLUMNS("P"LOADS IN KN)																M30		Fe500
COLUMN SIZE IN MM		PERCENTAGE OF STEEL REINFORCEMENT / LOAD CARRYING CAPACITY																
b	D	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00
230	230	514	537	560	583	605	628	651	674	697	719	742	765	788	810	833	856	879
230	300	671	701	730	760	790	819	849	879	909	938	968	998	1027	1057	1087	1117	1146
230	400	894	934	974	1013	1053	1093	1132	1172	1211	1251	1291	1330	1370	1410	1449	1489	1528
230	450	1006	1051	1095	1140	1185	1229	1274	1318	1363	1407	1452	1497	1541	1586	1630	1675	1719
230	500	1118	1168	1217	1267	1316	1366	1415	1465	1514	1564	1613	1663	1712	1762	1811	1861	1911
230	600	1342	1401	1461	1520	1579	1639	1698	1758	1817	1877	1936	1995	2055	2114	2174	2233	2293
230	750	1677	1751	1826	1900	1974	2049	2123	2197	2271	2346	2420	2494	2569	2643	2717	2792	2866
300	300	875	914	953	991	1030	1069	1108	1146	1185	1224	1263	1301	1340	1379	1418	1456	1495
300	400	1167	1218	1270	1322	1373	1425	1477	1528	1580	1632	1684	1735	1787	1839	1890	1942	1994
300	450	1313	1371	1429	1487	1545	1603	1661	1720	1778	1836	1894	1952	2010	2068	2127	2185	2243
300	500	1458	1523	1588	1652	1717	1781	1846	1911	1975	2040	2104	2169	2234	2298	2363	2427	2492
300	600	1750	1828	1905	1983	2060	2138	2215	2293	2370	2448	2525	2603	2680	2758	2835	2913	2990
300	750	2188	2285	2381	2478	2575	2672	2769	2866	2963	3060	3157	3254	3350	3447	3544	3641	3738
300	900	2625	2741	2858	2974	3090	3207	3323	3439	3555	3672	3788	3904	4020	4137	4253	4369	4486
400	400	1556	1625	1693	1762	1831	1900	1969	2038	2107	2176	2245	2314	2383	2451	2520	2589	2658
400	500	1945	2031	2117	2203	2289	2375	2461	2547	2634	2720	2806	2892	2978	3064	3150	3237	3323
400	600	2333	2437	2540	2644	2747	2850	2954	3057	3160	3264	3367	3470	3574	3677	3780	3884	3987
400	700	2722	2843	2964	3084	3205	3325	3446	3566	3687	3808	3928	4049	4169	4290	4411	4531	4652
400	800	3111	3249	3387	3525	3663	3800	3938	4076	4214	4352	4489	4627	4765	4903	5041	5178	5316
400	900	3500	3655	3810	3965	4120	4275	4430	4585	4740	4896	5051	5206	5361	5516	5671	5826	5981
450	450	1969	2056	2143	2230	2318	2405	2492	2579	2667	2754	2841	2928	3015	3103	3190	3277	3364
450	600	2625	2741	2858	2974	3090	3207	3323	3439	3555	3672	3788	3904	4020	4137	4253	4369	4486
450	750	3281	3427	3572	3717	3863	4008	4154	4299	4444	4590	4735	4880	5026	5171	5316	5462	5607
450	900	3938	4112	4287	4461	4635	4810	4984	5159	5333	5507	5682	5856	6031	6205	6380	6554	6728
600	600	3500	3655	3810	3965	4120	4275	4430	4585	4740	4896	5051	5206	5361	5516	5671	5826	5981
600	750	4375	4569	4763	4957	5150	5344	5538	5732	5926	6119	6313	6507	6701	6895	7088	7282	7476
600	900	5250	5483	5715	5948	6180	6413	6646	6878	7111	7343	7576	7808	8041	8274	8506	8739	8971

Table 1.7

Safe load carrying capacity of column based on % of steel and known column section for various grade of concrete and Steel.

Steel Grade → / Concrete Grade ↓	**Fe 415**	**Fe 500**
M20	P=(2.7005 p+ 8) bD/1500	P=(3.27p + 8) bD/1500
M25	P=(2.6805 p+ 10) bD/1500	P=(3.25p +10) bD/1500
M30.	P=(2.6605 p+ 12) bD/1500	P=(3.23p + 12) bD/1500
M35	P=(2.6405 p+ 14) bD/1500	P=(3.21p + 14) bD/1500
M40	P=(2.6205 p+ 16) bD/1500	P=(3.19p + 16) bD/1500

Where P is Axial Load carrying capacity of column in KN.

p = % of steel reinforcement (say 2% is 2)

b = Breadth of Column in mm

D = Depth of Column in mm.

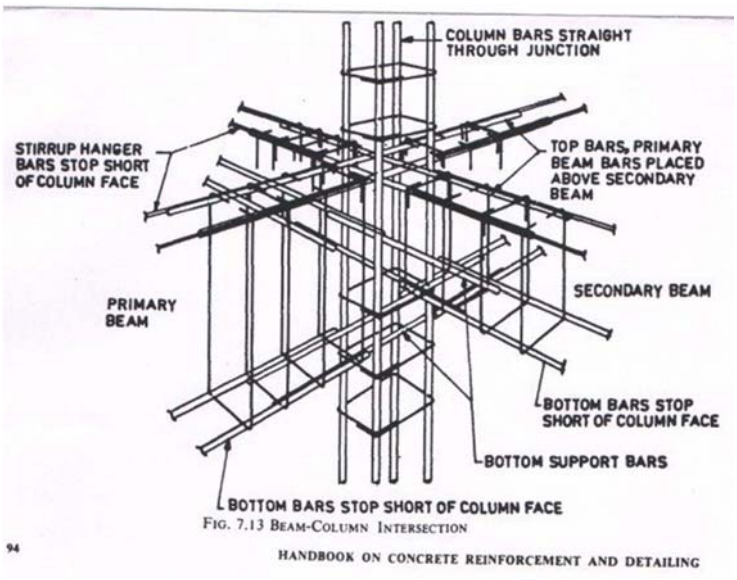


FIG. 7.13 BEAM-COLUMN INTERSECTION

4. FOOTINGS

Footings distribute the load transmitted from the column into the soil.

Size of footings depend on the type of soil on which the building rests.

S.B.C:

The safe bearing capacity (S.B.C) of soils like clay is very less.

S.B.C. of soils like hard gravel soil is high.

S.B.C. of soft / hard rock is very high.

In absence of Soil Test Results SBC is generally assumed as follows:-

- Clay = 100 KN/m² Coarse Sand =150 KN/m²
- Hard gravel = 250 KN/m2 Soft Disintegrated Rock =300 KN/m²
- However it is highly recommended to Conduct Soil Test by Soil Experts for adopting the SBC and type of foundation, before execution.

Footing Design

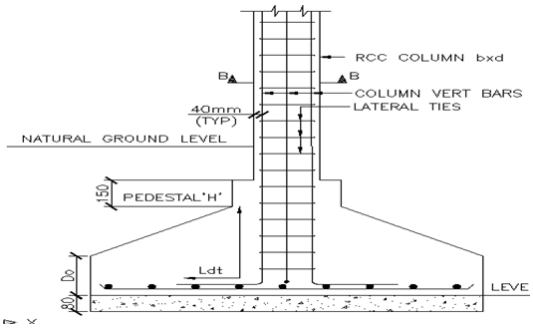
(i)Size of footing

Area of Footing, A = {(1.1 x Load On Column)/ (SBC of Soil)}

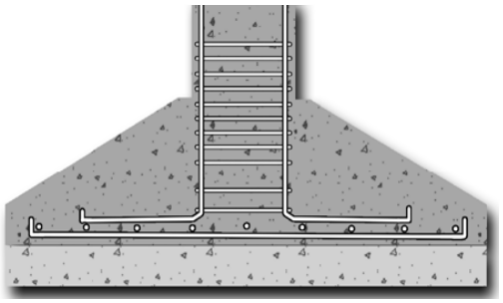
= {(1.1 x 800)/ (100)} = 8.80 m2

Size of square Footing (in Plan) = √A = √8.80 = 3.0m x 3.0m

Thickness of footing and reinforcement are arrived by designing the footing Slab as cantilever for the upward pressure exerted by the soil. However ready reckoners can be made use of.



Footing (with Pedestal)



Footing (without Pedestal)

(ii) Depth of Footing:

Depth footing can be calculated based on bending moment, one way shear and punching shear consideration. However depth of footing can be calculated using the following approximate method.

Net soil pressure in kN / m^2 (SBC of Soil)	T (m) (for Block Footing)	**D(m) (for Sloped and Stepped Footing)**
50	B/7	**1.2 (B/7)**
100	B/5.5	**1.2 (B/5.5)**
150	B/5.0	**1.2 (B/5.0)**
200	B /4.5	**1.2 (B /4.5)**
250	B /4.0	**1.2 (B /4.0)**
300	B /3.50	**1.2 (B /3.50)**

Where B = Size of footing in "m"

D = Total Thickness of Footing

(iii) Reinforcement:

Minimum Dia. of bar : 10 Φ RTS

Thumb rule:

Up to 2.0 m width : use 10 Φ RTS

Above 2.0m Up to 3.0 m width : use 12 Φ RTS

Above 3.0 m width : use 16 Φ RTS

Minimum spacing of bar : 100 mm

Maximum spacing of bar : 200 mm

Table 1a Ready Reckoner for Footing

M20 Fe 415 **SBC :100kN/m^2**

Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	1.10x1.10	30	20	3.1	5-10#
150	1.30x1.30	30	25	4.3	6-10#
200	1.50x1.50	30	30	5.5	8-10#
250	1.70x1.70	40	30	7	9-10#
300	1.90x1.90	40	35	8.1	11-10#
350	2.00x2.00	40	40	8.4	11-10#
400	2.10x2.10	40	40	10.9	14-10#
450	2.30x2.30	40	45	11.9	16-10#
500	2.40x2.40	40	50	12.1	16-10#
550	2.50x2.50	40	50	14.7	13-12#
600	2.60x2.60	40	55	14.8	14-12#
650	2.70x2.70	40	55	17.4	16-12#
700	2.80x2.80	40	60	17.4	16-12#
750	2.90x2.90	40	65	18.8	17-12#
800	3.00x3.00	40	65	20.1	18-12#
850	3.10x3.10	50	60	22.6	20-12#
900	3.20x3.20	50	65	22.3	20-12#
950	3.30x3.30	50	65	25.2	13-16#
1000	3.40x3.40	50	70	24.9	13-16#
1050	3.40x3.40	50	70	26.5	14-16#
1100	3.50x3.50	50	70	29.6	15-16#
1150	3.60x3.60	50	75	29	15-16#
1200	3.70x3.70	50	80	30.2	16-16#
1250	3.70x3.70	50	80	30.3	16-16#
1300	3.80x3.80	50	80	33.3	17-16#
1350	3.90x3.90	50	85	33.9	17-16#
1400	4.00x4.00	50	85	35.9	18-16#
1450	4.00x4.00	50	90	36.9	19-16#
1500	4.10x4.10	60	80	40.1	20-16#
1550	4.20x4.20	60	85	39.2	20-16#
1600	4.20x4.20	60	85	40.8	21-16#
1650	4.30x4.30	60	90	40.2	20-16#
1700	4.40x4.40	60	90	43.3	22-16#
1750	4.40x4.40	60	90	44.9	22-16#
1800	4.50x4.50	60	95	44.4	23-16#

NOTE: D = Total Thickness of Footing near Face of column

Table 2a Ready Reckoner for Footing

M20 Fe 415 **SBC:150kN/m^2**

Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.90x0.90	30	20	2	5-10#
150	1.10x1.10	30	25	3	5-10#
200	1.20x1.20	30	30	3.6	5-10#
250	1.40x1.40	40	30	4.8	7-10#
300	1.50x1.50	40	30	6.8	9-10#
350	1.60x1.60	40	35	7	9-10#
400	1.70x1.70	40	35	9.3	12-10#
450	1.90x1.90	40	40	10.4	14-10#
500	1.90x1.90	40	40	11.9	11-12#
550	2.00x2.00	40	45	11.9	11-12#
600	2.10x2.10	40	50	12	11-12#
650	2.20x2.20	40	50	14.4	13-12#
700	2.30x2.30	40	55	14.5	13-12#
750	2.40x2.40	40	55	17	16-12#
800	2.50x2.50	40	60	17	16-12#
850	2.50x2.50	40	60	18.4	17-12#
900	2.60x2.60	40	65	18.3	17-12#
950	2.70x2.70	40	65	21	19-12#
1000	2.70x2.70	50	60	21.7	20-12#
1100	2.90x2.90	50	65	24.2	13-16#
1200	3.00x3.00	50	70	25.2	13-16#
1300	3.10x3.10	50	75	26.3	14-16#
1400	3.20x3.20	50	75	30.5	16-16#
1500	3.40x3.40	60	75	32.2	17-16#
1600	3.50x3.50	60	75	36.8	19-16#
1700	3.60x3.60	60	80	37.4	19-16#
1800	3.70x3.70	60	85	38.1	19-16#
1900	3.80x3.80	70	80	41.9	21-16#
2000	3.90x3.90	70	80	47	24-16#
2100	4.00x4.00	70	85	47.2	24-16#
2200	4.10x4.10	70	90	47.5	24-16#
2300	4.10x4.10	70	90	50.2	25-16#
2400	4.20x4.20	70	95	50.5	25-16#
2500	4.30x4.30	80	90	54.6	27-16#

NOTE: D = Total Thickness of Footing near Face of column

Table 3a Ready Reckoner for Footing

M20 Fe 415 **SBC:200kN/m^2**

Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.8x0.8	30	30	3.2	5-10#
150	1.00x1.00	30	30	3.9	6-10#
200	1.10x1.10	30	30	4.3	7-10#
250	1.20x1.20	40	30	5	8-10#
300	1.30x1.30	40	30	5.4	8-10#
350	1.40x1.40	40	30	6.7	9-10#
400	1.50x1.50	40	35	7.1	9-10#
450	1.60x1.60	40	45	9	12-10#
500	1.70x1.70	40	40	9.2	12-10#
550	1.80x1.80	40	40	10.9	14-10#
600	1.90x1.90	40	45	11	11-12#
650	1.90x1.90	40	45	12.8	12-12#
700	2.00x2.00	40	50	12.8	12-12#
750	2.10x2.10	40	50	14.6	13-12#
800	2.10x2.10	40	55	14.2	13-12#
850	2.20x2.20	40	55	16.5	15-12#
900	2.30x2.30	40	60	16.5	15-12#
950	2.30x2.30	40	60	17.7	16-12#
1000	2.40x2.40	50	55	18.9	17-12#
1100	2.50x2.50	50	60	20.6	18-12#
1200	2.60x2.60	50	65	24.8	15-16#
1300	2.70x2.70	50	65	25.6	16-16#
1400	2.80x2.80	50	70	26.5	16-16#
1500	2.90x2.90	60	65	29.9	18-16#
1600	3.00x3.00	60	70	30.5	16-16#
1700	3.10x3.10	60	75	35	17-16#
1800	3.20x3.20	60	75	34.5	17-16#
1900	3.30x3.30	70	70	38.3	20-16#
2000	3.40x3.40	70	75	38.5	20-16#
2100	3.40x3.40	70	75	42.2	21-16#
2200	3.50x3.50	70	80	42.4	21-16#
2300	3.60x3.60	70	85	47.3	24-16#
2400	3.70x3.70	70	85	46.3	24-16#
2500	3.80x3.80	80	90	50.3	26-16#

NOTE: D = Total Thickness of Footing near Face of column

Table 4a Ready Reckoner for Footing

M20 Fe 415 **SBC:250kN/m^2**

Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.70x0.70	30	20	1.2	4-10#
150	0.80x0.80	30	25	1.9	4-10#
200	1.00x1.00	30	30	2.9	4-10#
250	1.10x1.10	40	30	3.3	5-10#
300	1.20x1.20	40	30	4.2	6-10#
350	1.30x1.30	40	35	4.6	6-10#
400	1.40x1.40	40	35	6.2	8-10#
450	1.40x1.40	40	40	5.8	8-10#
500	1.50x1.50	40	40	7.5	10-10#
550	1.60x1.60	40	45	7.8	10-10#
600	1.70x1.70	40	45	9.7	13-10#
650	1.70x1.70	40	45	10.7	14-10#
700	1.80x1.80	40	50	10.9	14-10#
750	1.90x1.90	40	50	13.1	17-10#
800	1.90x1.90	40	50	14.2	13-12#
850	2.00x2.00	40	55	14.3	13-12#
900	2.00x2.00	40	55	15.3	14-12#
950	2.10x2.10	50	55	14.7	13-12#
1000	2.10x2.10	50	55	15.6	14-12#
1100	2.20x2.20	50	60	16.7	15-12#
1200	2.30x2.30	50	60	20.1	18-12#
1300	2.40x2.40	50	65	21.1	19-12#
1400	2.50x2.50	50	65	25	13-16#
1500	2.60x2.60	60	65	24.8	13-16#
1600	2.70x2.70	60	70	25.5	13-16#
1700	2.80x2.80	60	70	29.5	15-16#
1800	2.80x2.80	60	75	28.3	15-16#
1900	2.90x2.90	70	70	31.3	16-16#
2000	3.00x3.00	70	75	31.8	16-16#
2100	3.10x3.10	70	75	36	18-16#
2200	3.10x3.10	70	80	34.4	18-16#
2300	3.20x3.20	70	80	38.6	20-16#
2400	3.30x3.30	80	80	38	19-16#
2500	3.40x3.40	80	80	42.3	22-16#
2600	3.40x3.40	80	85	40.4	20-16#
2700	3.50x3.50	80	85	44.7	23-16#
2800	3.50x3.50	80	85	46.7	24-16#
2900	3.60x3.60	90	85	46	23-16#
3000	3.70x3.70	90	85	50.6	26-16#

NOTE: D = Total Thickness of Footing near Face of column

Thickness of Footing at Free End (D_0)

D	≤ 650	700	800	900	1000	1200
D_0	200	250	300	350	400	450

Table 5

Development Lengths for various concrete Grades & Steel Fe 415

Conc. Grade	M15	M20	M25	M30	M35	M40
Ld (Tension)	57 Ø	47 Ø	40 Ø	38 Ø	33 Ø	30 Ø
Ld (Compression)	52 Ø	38 Ø	32 Ø	30 Ø	27 Ø	24 Ø

Table 6

Development Lengths for various concrete Grades & Steel Fe 500

Conc. Grade	M15	M20	M25	M30	M35	M40
Ld (Tension)	68 Ø	57 Ø	49 Ø	45 Ø	40 Ø	36 Ø
Ld (Compression)	57 Ø	46 Ø	39 Ø	36 Ø	32 Ø	29 Ø

Table 1b Ready Reckoner for Footing

				M20 Fe 500	**SBC 100kN/m^2**
Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	1.10x1.10	30	30	4.3	7-10#
150	1.30x1.30	30	30	5.3	8-10#
200	1.50x1.50	30	30	6	9-10#
250	1.70x1.70	40	30	6.9	10-10#
300	1.90x1.90	40	35	8.6	11-10#
350	2.00x2.00	40	40	10.4	14-10#
400	2.10x2.10	40	40	10.9	14-10#
450	2.30x2.30	40	45	13	17-10#
500	2.40x2.40	40	45	13.5	19-10#
550	2.50x2.50	40	50	15.7	15-12#
600	2.60x2.60	40	55	17.8	16-12#
650	2.70x2.70	40	55	18.5	17-12#
700	2.80x2.80	40	60	20.7	19-12#
750	2.90x2.90	40	65	23	21-12#
800	3.00x3.00	40	65	23.8	21-12#
850	3.10x3.10	50	60	23.1	21-12#
900	3.20x3.20	50	65	25.6	23-12#
950	3.30x3.30	50	65	26	23-12#
1000	3.40x3.40	50	70	28.7	25-12#
1050	3.40x3.40	50	70	29.1	20-16#
1100	3.50x3.50	50	75	31.8	20-16#
1150	3.60x3.60	50	75	32.7	21-16#
1200	3.70x3.70	50	75	33.1	21-16#
1250	3.70x3.70	50	80	36	22-16#
1300	3.80x3.80	50	80	36.5	22-16#
1350	3.90x3.90	50	85	39.5	23-16#
1400	4.00x4.00	50	85	40	24-16#
1450	4.00x4.00	50	90	42.7	23-16#
1500	4.10x4.10	60	80	39.7	24-16#
1550	4.20x4.20	60	85	42.5	24-16#
1600	4.20x4.20	60	85	43	24-16#
1650	4.30x4.30	60	90	46.4	25-16#
1700	4.40x4.40	60	90	46.8	25-16#
1750	4.40x4.40	60	90	47.3	25-16#
1800	4.50x4.50	60	95	50.4	26-16#

NOTE: D = Total Thickness of Footing near Face of column

Table 2b Ready Reckoner for Footing

				M20 Fe 500	**SBC:150kN/m^2**
Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.90x0.90	30	30	3.8	5-10#
150	1.10x1.10	30	30	4.3	6-10#
200	1.20x1.20	30	30	5.1	6-10#
250	1.40x1.40	40	30	5.7	7-10#
300	1.50x1.50	40	30	6.1	9-10#
350	1.60x1.60	40	35	7.7	10-10#
400	1.70x1.70	40	35	8.2	11-10#
450	1.90x1.90	40	40	9.7	12-10#
500	1.90x1.90	40	40	10.2	11-12#
550	2.00x2.00	40	45	11.9	12-12#
600	2.10x2.10	40	50	13.4	13-12#
650	2.20x2.20	40	50	14	13-12#
700	2.30x2.30	40	55	15.9	14-12#
750	2.40x2.40	40	55	16.2	14-12#
800	2.50x2.50	40	60	18.3	17-12#
850	2.50x2.50	40	60	18.6	17-12#
900	2.60x2.60	40	65	20.8	18-12#
950	2.70x2.70	40	65	21.2	19-12#
1000	2.70x2.70	50	60	20.7	19-12#
1100	2.90x2.90	50	65	23.6	20-12#
1200	3.00x3.00	50	70	25.9	18-16#
1300	3.10x3.10	50	75	28.5	19-16#
1400	3.20x3.20	50	75	29.8	19-16#
1500	3.40x3.40	60	75	31.1	20-16#
1600	3.50x3.50	60	75	32	20-16#
1700	3.60x3.60	60	80	34.9	22-16#
1800	3.70x3.70	60	85	37.9	24-16#
1900	3.80x3.80	70	80	37.2	24-16#
2000	3.90x3.90	70	80	38.1	23-16#
2100	4.00x4.00	70	85	41.3	24-16#
2200	4.10x4.10	70	90	44.6	24-16#
2300	4.10x4.10	70	90	45.6	25-16#
2400	4.20x4.20	70	95	48.6	26-16#
2500	4.30x4.30	80	90	47.8	26-16#

NOTE: D = Total Thickness of Footing near Face of column

Table 3b Ready Reckoner for Footing

				M20 Fe 500	**SBC:200kN/m^2**
Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.8x0.8	30	30	3.2	5-10#
150	1.00x1.00	30	30	3.9	6-10#
200	1.10x1.10	30	30	4.3	7-10#
250	1.20x1.20	40	30	5	8-10#
300	1.30x1.30	40	30	5.4	8-10#
350	1.40x1.40	40	30	6.1	9-10#
400	1.50x1.50	40	35	7.1	10-10#
450	1.60x1.60	40	45	7.5	10-10#
500	1.70x1.70	40	40	9	12-10#
550	1.80x1.80	40	40	9.2	12-10#
600	1.90x1.90	40	45	10.8	11-12#
650	1.90x1.90	40	45	11.1	11-12#
700	2.00x2.00	40	50	12.8	12-12#
750	2.10x2.10	40	50	13.1	13-12#
800	2.10x2.10	40	55	14.6	13-12#
850	2.20x2.20	40	55	15.3	14-12#
900	2.30x2.30	40	60	16.9	15-12#
950	2.30x2.30	40	60	17.5	16-12#
1000	2.40x2.40	50	55	16.6	15-12#
1100	2.50x2.50	50	60	19	17-12#
1200	2.60x2.60	50	65	21.3	15-16#
1300	2.70x2.70	50	65	22	16-16#
1400	2.80x2.80	50	70	24.4	16-16#
1500	2.90x2.90	60	65	24.8	17-16#
1600	3.00x3.00	60	70	26.4	16-16#
1700	3.10x3.10	60	75	29	18-16#
1800	3.20x3.20	60	75	29.5	18-16#
1900	3.30x3.30	70	70	31.8	19-16#
2000	3.40x3.40	70	75	32	20-16#
2100	3.40x3.40	70	75	35	21-16#
2200	3.50x3.50	70	80	35.2	21-16#
2300	3.60x3.60	70	85	38	22-16#
2400	3.70x3.70	70	85	38.5	22-16#
2500	3.80x3.80	80	90	41.7	23-16#

NOTE: D = Total Thickness of Footing near Face of column

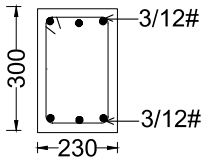
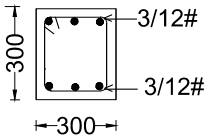
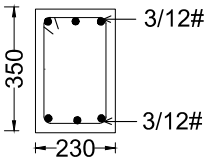
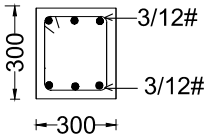
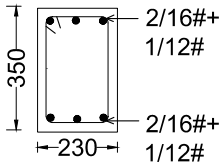
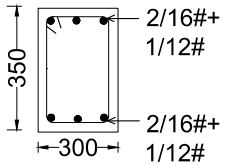
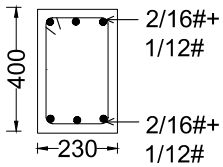
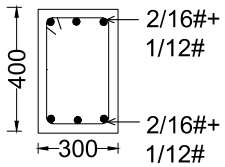
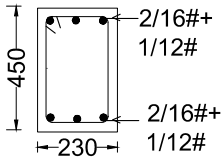
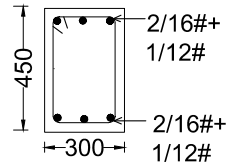
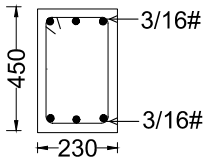
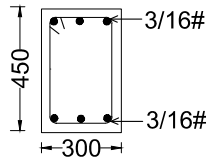
Table 4b Ready Reckoner for Footing

M20 Fe 500 **SBC:250kN/m²**

Load in kN	Footing Size (m x m)	Least dimension of column pedestal	D in cm	Reinforcement area in each direction in cm^2	Reinforcement in each direction
100	0.70x0.70	30	30	3	5-10#
150	0.80x0.80	30	30	3.6	5-10#
200	1.00x1.00	30	30	4	6-10#
250	1.10x1.10	40	30	4.4	7-10#
300	1.20x1.20	40	30	4.8	8-10#
350	1.30x1.30	40	30	5.2	8-10#
400	1.40x1.40	40	30	7.6	10-10#
450	1.40x1.40	40	35	6.8	9-10#
500	1.50x1.50	40	35	8.6	11-10#
550	1.60x1.60	40	40	8.9	11-10#
600	1.70x1.70	40	40	9.4	12-10#
650	1.70x1.70	40	45	10	13-10#
700	1.80x1.80	40	45	10.5	14-10#
750	1.90x1.90	40	50	11.4	15-10#
800	1.90x1.90	40	50	12.2	16-10#
850	2.00x2.00	40	50	13	12-12#
900	2.00x2.00	40	55	14	13-12#
950	2.10x2.10	50	50	13.4	12-12#
1000	2.10x2.10	50	50	15.5	14-12#
1100	2.20x2.20	50	55	15.6	14-12#
1200	2.30x2.30	50	60	17.7	16-12#
1300	2.40x2.40	50	60	19.5	18-12#
1400	2.50x2.50	50	65	20.5	15-16#
1500	2.60x2.60	60	60	22.9	16-16#
1600	2.70x2.70	60	65	23.4	16-16#
1700	2.80x2.80	60	65	26.2	18-16#
1800	2.80x2.80	60	70	26.6	18-16#
1900	2.90x2.90	70	65	28.7	20-16#
2000	3.00x3.00	70	70	28.9	18-16#
2100	3.10x3.10	70	70	31.8	20-16#
2200	3.10x3.10	70	75	32	22-16#
2300	3.20x3.20	70	75	34.9	22-16#
2400	3.30x3.30	80	70	39.1	20-16#
2500	3.40x3.40	80	75	37.1	19-16#
2600	3.40x3.40	80	75	40.2	21-16#
2700	3.50x3.50	80	80	39	20-16#
2800	3.50x3.50	80	80	43.3	22-16#
2900	3.60x3.60	90	75	48.1	24-16#
3000	3.70x3.70	90	80	44.2	22-16#

NOTE: D = Total Thickness of Footing near Face of column

Ready Reckoner for Grade Beams

	Grade Beam Details for storey height of 3.30 m with 1.20 m basement height.			Concrete M20 Fe 415 Steel.
	Span in m.	GRAVITY DESIGN	SEISMIC DESIGN	REMARKS
1	3.00 to 3.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
2	3.50 to 4.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
3	4.00 to 4.50 m			
		STP.2L-8#@ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
4	4.50 to 5.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
5	5.00 to 5.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
6	5.50 to 6.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	

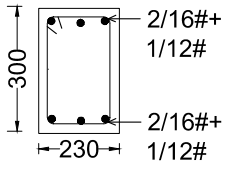
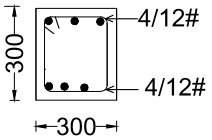
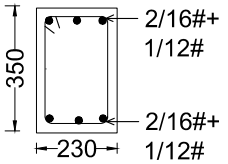
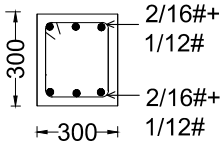
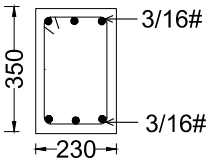
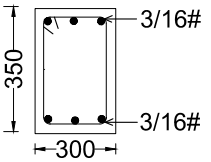
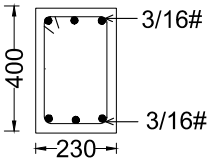
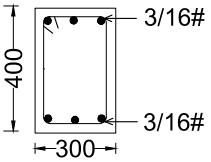
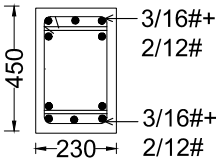
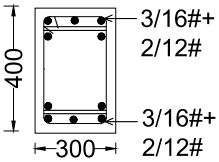
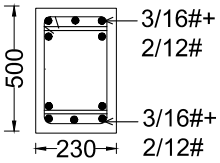
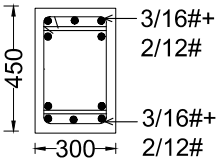
Note:

1. Grade beams designed for 230mm wall loads for a storey height of 3.3 m & basement height 1.20 m.
2. M20 & Fe415 Grade to be adopted.
3. Adopt Ductile detailing as per IS 13920 for Seismic design.
4. This is not applicable for Grade beams loaded with Point loads due to secondary beams.
5. Load due to Structural slab is not considered for design.

Grade Beam Details for storey height of 4.95m with 1.20 m basement height.

Concrete M20

Fe 415 Steel.

	Span in m.	GRAVITY DESIGN	SEISMIC DESIGN	REMARKS
1	3.00 to 3.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
2	3.50 to 4.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
3	4.00 to 4.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
4	4.50 to 5.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
5	5.00 to 5.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
6	5.50 to 6.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	

Note:

1. Grade beams designed for 230mm wall loads for a storey height of 4.95 m & basement height 1.20 m.
2. M20 & Fe415 Grade to be adopted.
3. Adopt Ductile detailing as per IS 13920 for Seismic design.
4. This is not applicable for Grade beams loaded with Point loads due to secondary beams.
5. Load due to Structural slab is not considered for design.

Ready Reckoner for Stair Waist Slab

M20 Fe415

Span (m)	Waist thickness D mm	IL=3.00KN/m^2		IL=5.00KN/m^2	
		MAIN REBARS	DISTRIBUTORS	MAIN REBARS	DISTRIBUTORS
2.40	115	8mm @ 200 c/c	8mm @ 250 c/c	8mm @ 180 c/c	8mm @ 250 c/c
3.00	125	8mm @ 150 c/c	8mm @ 250 c/c	8mm @ 125 c/c	8mm @ 250 c/c
3.50	125	8mm @ 100 c/c	8mm @ 250 c/c	10mm @ 125 c/c	8mm @ 250 c/c
4.00	135	10mm @ 125 c/c	8mm @ 250 c/c	12mm @ 150 c/c	8mm @ 250 c/c
4.50	150	12mm @ 180 c/c	8mm @ 250 c/c	12mm @ 150 c/c	8mm @ 250 c/c
5.00	175	12mm @ 180 c/c	8mm @ 250 c/c	12mm @ 150 c/c	8mm @ 250 c/c
5.50	175	12mm @ 150 c/c	8mm @ 250 c/c	12mm @ 125 c/c	8mm @ 250 c/c
6.00	200	12mm @ 125 c/c	8mm @ 230 c/c	12mm @ 100 c/c	8mm @ 230 c/c
6.50	200	12mm @ 100 c/c	8mm @ 230 c/c	12mm @ 100 c/c	8mm @ 230 c/c
7.00	230	12mm @ 100 c/c	8mm @ 200 c/c	12mm @ 100 c/c	8mm @ 200 c/c

Caution

Though this chapter has been produced to guide the Civil engineers involved in building construction, the approximate methods and ready reckoners presented here are to be used with care, since they are based on certain assumptions; for example,

- The coefficients adopted for calculating column loads are based on the assumption that the building consist of Full wall on outer boundaries and Partition wall in interior portions. Suitable consideration is to be paid if it is not so. Similarly for Staircase and Toilet portions suitable additional loads are to be added.
- The spans of beams assumed are small/moderate and are not very long to create moments in Columns. If significant moments are expected, rational additional loads may be considered to account for this.

  Hence it is advised to use these techniques with Civil Engineering sense and Intuition.

CHAPTER - II

CANTILEVERS

Design Methodology Adopted for cantilevers like Canopy Slab of bus stands

The Cantilever Structures are one of the weakest links in any building. Long Cantiliever structures (except sunshades for Windows, Ventilator etc.) made by reinforced cement concrete should be avoided as far as possible since this become weak with the passage of time.

Canopy Slab of bus stands are generally designed and constructed by any one of the following three Methods:-

Method 1:-

This method is adopted when edge beams are provided at the free end as well as the supporting end. In this method, slab will be designed and constructed as Single span - One Way Slab spanning between the edge beams. (ref. fig.2.1).

Here the main reinforcements in slab are placed perpendicular to edge beam at the bottom and distribution steel reinforcements are placed just above the main reinforcements, parallel to the edge beams.

For this type of slab, the reinforcement arrangements should be provided as shown below. (ref. fig.2.1).

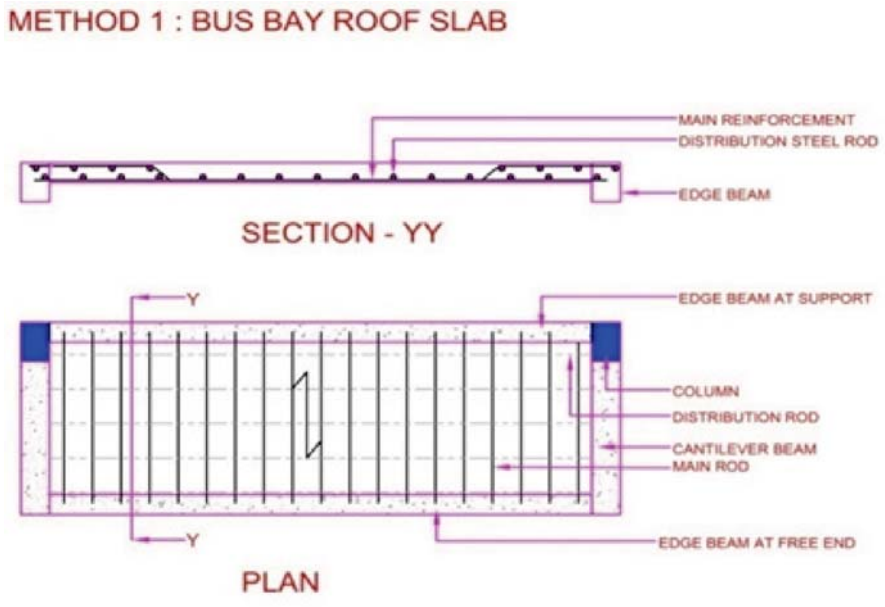


Fig 2.1 Slabs over Bus Bay–Method1

Method 2:-

This method is adopted when edge beams are provided only at the support end and there is no edge beam at the free end.

In this method slab will be designed as One-Way-Continuous Slab spanning between the cantilever beams.

Here the main reinforcements in slab are placed perpendicular to cantilever beams at the bottom and distribution steel reinforcements are placed just above the main reinforcements, parallel to the cantilever beams.

For this type of slab, the reinforcement arrangements should be provided as shown below. (ref. fig.2.2).

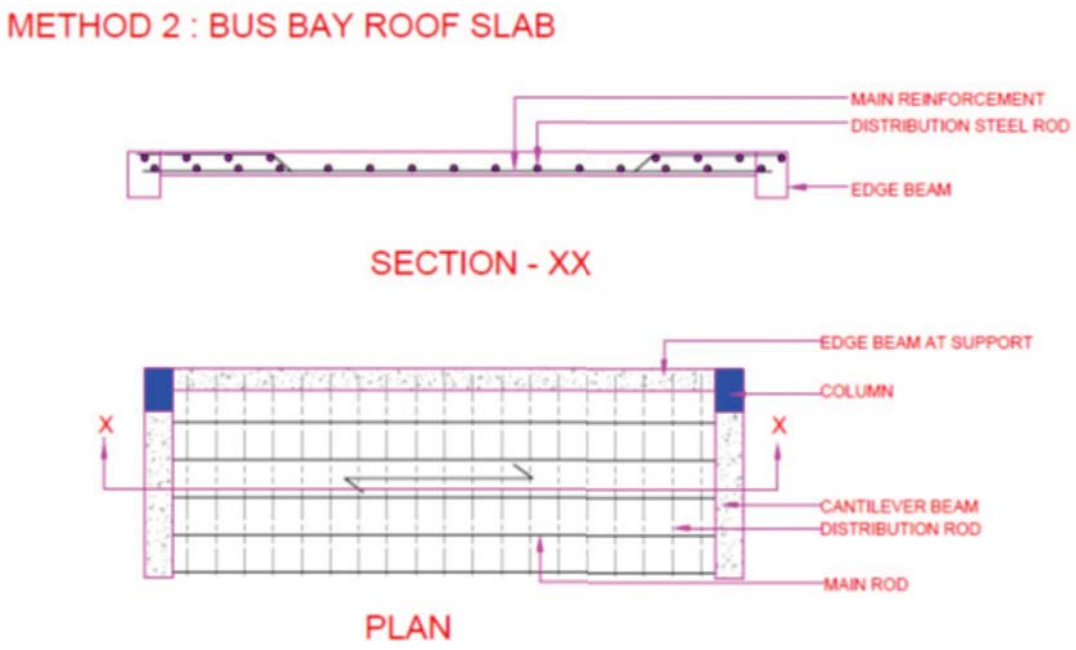


Fig 2.2 Slabs over Bus Bay–Method 2

Method 3:-

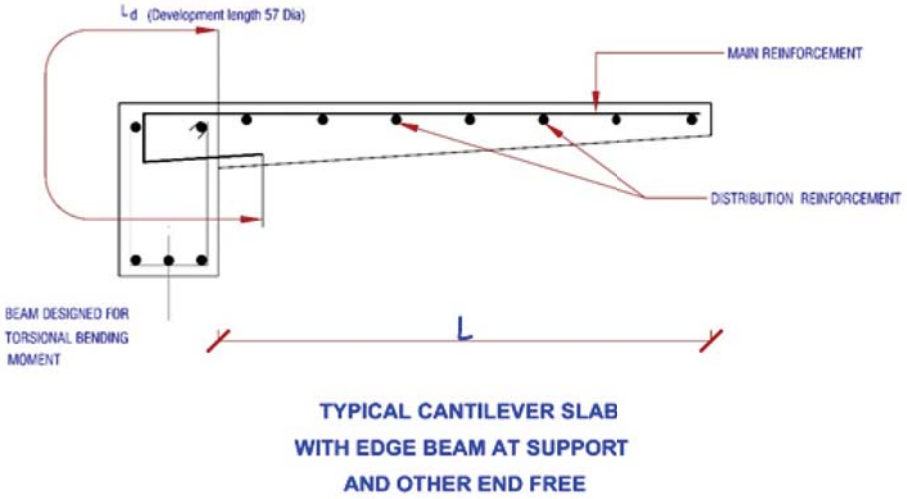
This method is generally adopted for window sun shades of buildings.

The projecting length or span of this type of cantilever slab will be very small in the range of 1.0 to 1.20 m .These type of slabs are risky since they are susceptible for rotation and collapse if not meticulously designed and carefully executed.

In this method, slab will be designed as a cantilever Slab with edge beam provided at the supporting end of the slab to avoid rotation.

For this type of slab, the reinforcement arrangements should be provided as shown below. (ref. fig.2.3).

As per the observations made on site, **the Method 3 which is generally adopted** only for window sunshades was adopted in the collapsed bus stand portion. located in Somanur hamlet of Karumathampatti Town Panchayat in Coimbatore



Slabs over Bus Bay –Method 3

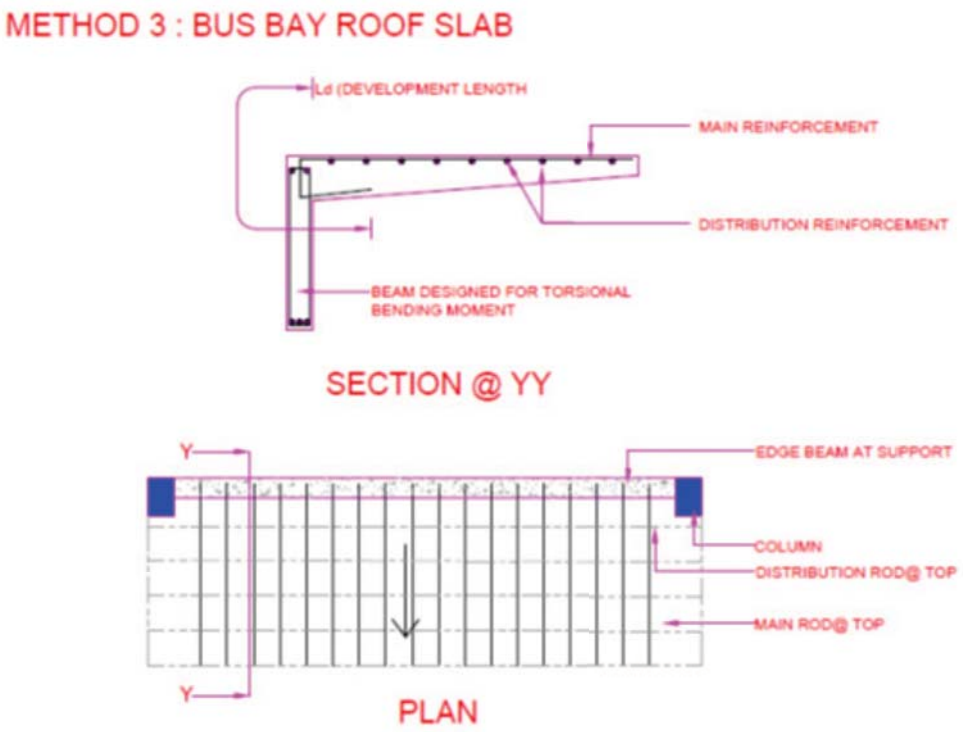


Fig 2.3. Slabs over Bus Bay –Method 3

Fig 2.4. Slabs over Bus Bay –Method 3
(Bus Stand at Kinathukadavu in Coimbatore)

When normal practice of designing and providing one way slabs by Method 1 or Method 2 are adopted for bus bays, load imposed on the slab gets transferred to the Cantilever beams (50% and 100% respectively) which in turn gets transmitted to the column.

Required reinforcement in appropriate direction and position for slab and cantilever beam have to be provided and also proper anchoring of top reinforcement of cantilever beam into the column for specified development length has to be ensured.

Recommendation for Bus Bays

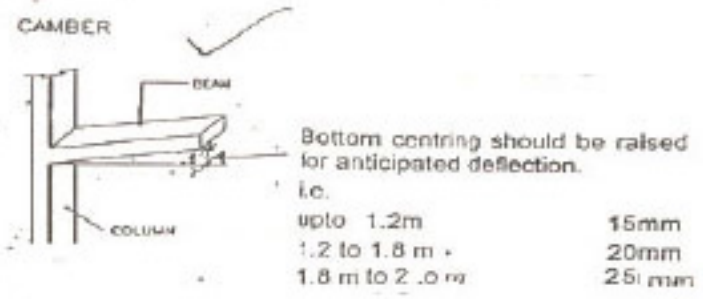
Projected cantilevers slabs over bus bays are to be provided at same level as that of the roof slab over shops on rear side. This is similar to Type 1 or 2 but Cantilever Slabs and Beams are continued in to the shop bay This is preferred from stability point of view. (Fig 2.5 & 2.6)

Fig 2.5 Recommended Type of Bus Stand (Avanashi, Coimbatore)

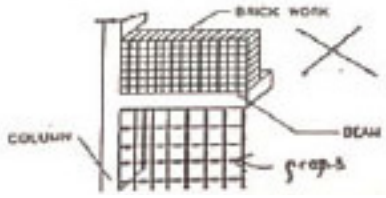
Fig 2.6 Type of Bus Stand to be avoided.

PRECAUTIONS

I. camber must be provided in cantilever slabs/beams to compensate the anticipated deflection.



II. Masonry wall should not be constructed above cantilever beams/slabs before removal of centering.



CHAPTER -III

COLLAPSE OF CANTILEVR SLAB – a case study

ROOF COLLAPSE OF BUS STAND AT SOMANUR HAMLET KARUMATHAMPATTI TOWN PANCHAYAT, COIMBATORE DISTRICT ON 07-09-2017

Bus stand – During usage (Added later with Parapet & PVC OHT)

Bus stand – Originally constructed

Bus stand – On Collapse

- The direct and indirect causes of collapses of the structures mainly three, singly or in combination, i.e. Design error, construction error and / or material deficiency. It is observed that if a collapses occurs a few years after occupancy, it is usually as a result of design error, either a part or a main cause. Sometimes, depending upon the time lapsed after completion of the structure and its subsequent occupancy, the factors contributing in accelerating the collapse would depend on basic design deficiency, workmanship and material deficiency.

3.1 Details of Original Construction and Additional Construction:

Original construction:

- The building is a framed structure building with Columns and Beams arrangement. The walls are panel walls in Brick work of 23cm thick and the partition walls are 11.5cm thick.
- The Building had been designed for G+ 1 (ultimate) Floors as per Records available in the Somanur town Panchayat office.
- The original Bus stand structure was constructed with Ground Floor only.

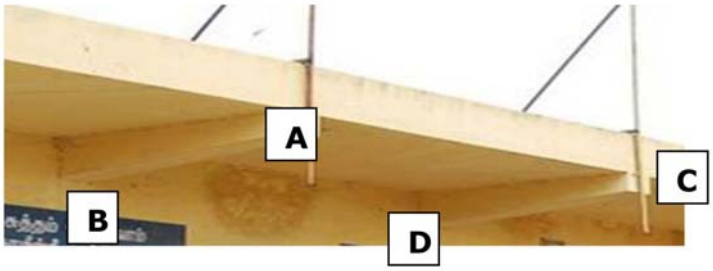
3.2 Additional Construction

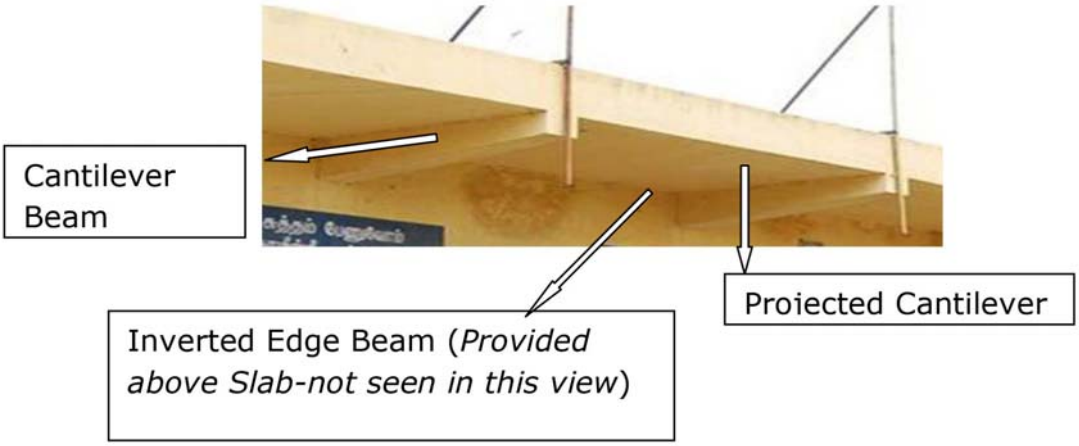
- Parapet wall at the free end of canopy was constructed after the Bus stand was opened to public. There is no record available to find out the date/year of construction of the Parapet wall.
- PVC Over Head Tank of 2000 litres capacity was provided over Cantilever slab portion subsequently causing additional unwanted load on the canopy located above the Bus bays.

3.3 Site Observations

Following interpretations were made during the site inspection.

1. The building consists of shops provided on rear side and bus bays at front (now collapsed).
2. Before the collapse, the front side of the building had a projected Cantilever Roof Slab with support on Cantilever Beams at their bottom, which were connected to columns provided at shop side (rear side).
3. It was observed that this projected Cantilevers Slab had been provided at higher level than the roof slab of the shops on rear side.
4. A PVC Over Head Tank of 2000 litres capacity had been provided over the Cantilever Slab and it was found damaged and broken.
5. The projectited canopy slab at the roof was supported on Cantilever Beams at two sides and was also supported on rear side by edge beams. Cantilever Slabs were continuous from left to right on cantilever beams. Also Cantilever Slabs were discontinuous beyond edge beams at rear side, and free without edge beams at front side.





Bus Stand at Somanur- Before Collapse

1. As per the observations made on site, the Method 3 which is generally adopted only for window sunshades was adopted in the collapsed bus stand portion.
2. When normal practice of designing and providing one way slabs by Method 1 or Method 2 are adopted for bus bays, load imposed on the slab gets transferred to the Cantilever beam which in turn gets transmitted to the column.
3. Required reinforcement in appropriate direction and position for slab and cantilever beam have to be provided and also proper anchoring of top reinforcement of cantilever beam into the column for specified development length has to be ensured.
4. From the broken portions of Cantilever Beams kept in debris, it was observed that though sufficient Beam-size for Cantilever Beam, required reinforcements as well as adequate Anchorage were provided in the Cantilever beam, the failure was due to inadequate thickness of Cantilever Slab and inadequate size of Edge beam provided. Further the reinforcements provided for the cantilever slab and edge beams were insufficient and also placed improperly.

Cantilever Beam with adequate anchorage

3.4 Cause of Failure:

Analysis:-

From the broken portions of slabs the following facts were evaluated:-

I. It could be assessed that the collapsed projected slab had been constructed assuming it as a Cantilever Slab projecting from tthe edge beam similar to a sunshade projected from the lintel-beam normally provided over windows of buildings.

II. Main Reinforcements were provided at the top of slab (12mm dia. @130mm spacing) along the Cantilever span of 2.0 m. Distribution steel was provided at the top of the slab along 6.0 m span.

III. Hence from slab, no load (or very meager load) had been transferred to Cantilever beams provided at their ends for that purpose. Actually cantilever beams provided did not contribute at all in sharing loading and they were in-effective and redundant because of the faulty structural arrangement followed.

Comparison of Structural Details as per Design calculation evolved now with the collapsed one

i) Cantilever Slab (with Water Tank & Parapet)

Particulars	**Required As per design calculation**	**Provided in the observed collapsed slabs**	**Remarks**
Slab Thickness	230 mm	120 mm	**Slab thickness inadequate**
Main reinforcement (Perpendicular to edge beam)	12mm Dia rods @ 125mm Centre to Centre	12T @ 130 (Top)	**Incorrect arrangement of bars**
Distribution	10T @ 200	10T@ 160	-

Hence from the above, it can be inferred that the slab thickness provided **was far below the requirement**.

ii) Cantilever slab (Before providing Water tank & Parapet)

Particulars	**Required** As per design calculation	**Provided** in the observed collapsed slabs	Remarks
Slab thickness	180 mm	120 mm	**Slab thickness inadequate**
Main reinforcement (Perpendicular to edge beam)	12T@ 150 Top	12T @ 130 (Top)	--
Distribution	10T @ 200	10T@ 160	**Incorrect arrangement of bars**

From the above also it can be inferred that the slab thickness provided was below the requirement.

iii) Edge beam (provided at Rear end of Cantilever Slab):

	As per calculation Evolved	Provided actually	Remarks
size	300X750	230X300	Beam size inadequate
Longitudinal reinforcement	5-20 (Top) 2-20 (Bottom)	3-16 (Top) 3-16 (Bottom)	Reinforcement insufficient
Shear Stirrups	10T@ 150	8T@ 170	Reinforcement insufficient
Side face reinforcement	2-12 (recommended)	-	Reinforcement insufficient

3.5 Interpretation:

(i) From the above calculations and observations made at site, it is evident that providing insufficient size & reinforcement in Cantilever Slabs & Edge Beams has resulted in the collapse of the structure. The structurally defective “Projected Cantilever Slab” would have failed first by deflection and rotation inducing torsion in the edge beam provided at its supporting end.

(ii) Edge beam is also weak and not strong enough to withstand the torsion induced in it due to the deflection of “Projected Cantilever Slab”.

(iii) Rotation of Edge Beams caused the ‘Tilting’ and ‘Detaching’ of the cantilever beams integrated with them.

(iv) The whole set of Cantilever Slabs, Edge Beams & Cantilever Beams collapsed suddenly because of structural deficiency and being characteristic of cantilever structures, the failure of cantilever structures was sudden without giving any warning.

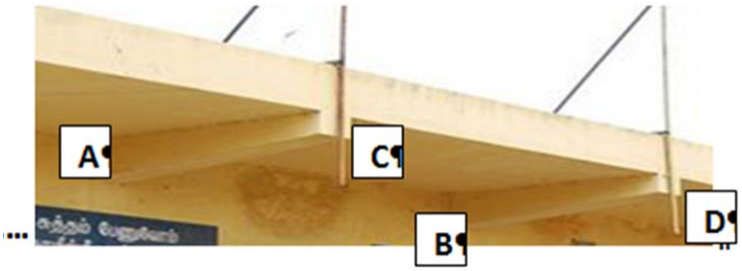
(v) Inherent Factor of Safety in load calculation, Design formulae and material parameters etc., are the reasons for the stability of projected Cantilever Slab for the past 17 years. The Bus Bay roof was built in the year 2000. Though the bus bay with projected cantilever slab was built with insufficient thickness of 120 mm

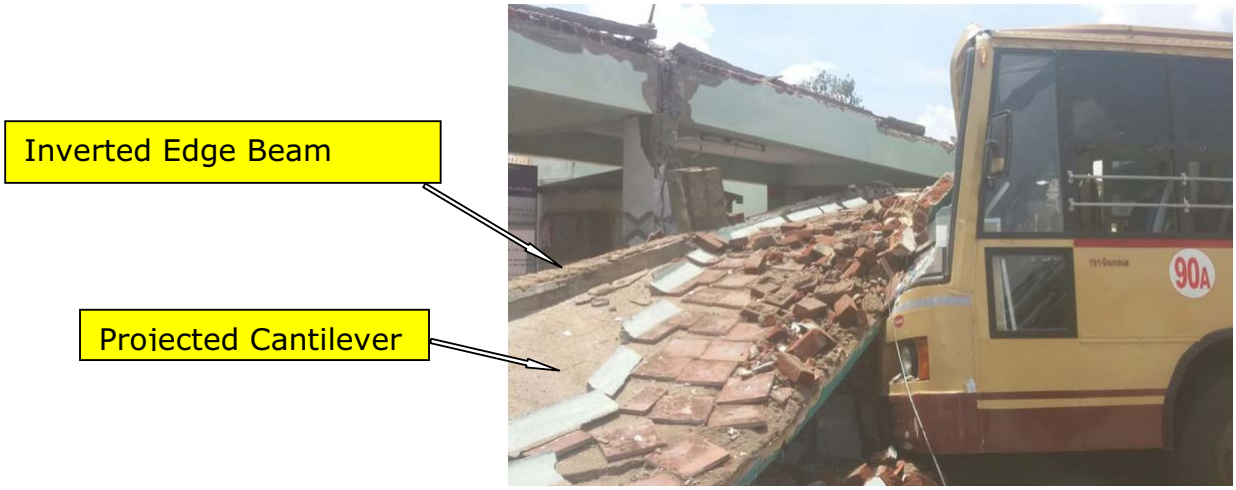
instead of required thickness of 180 mm, it was stable for about 17 years under the mercy of Factor of Safety.

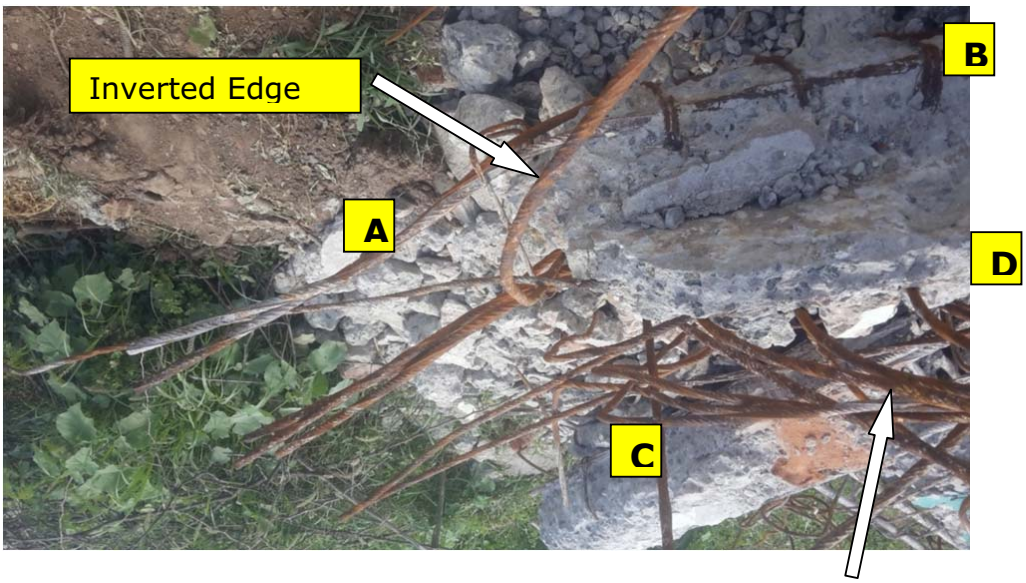
(vi) This Factor of Safety has been encroached upon later because of the extra load due a huge Water tank of 2000 litres (approximately 2 Tonnes of Load) capacity on this slab.

(vii) A Parapet wall was built on this Cantilever Slab at its free edge in the later years and thus, its Factor of Safety was further encroached upon substantially.

(viii) Finally when rainwater got stagnated on the roof, further addition of load had resulted in crossing over of the remaining inherent Factor of Safety which caused the ultimate collapse of the slab.







CHAPTER - IV

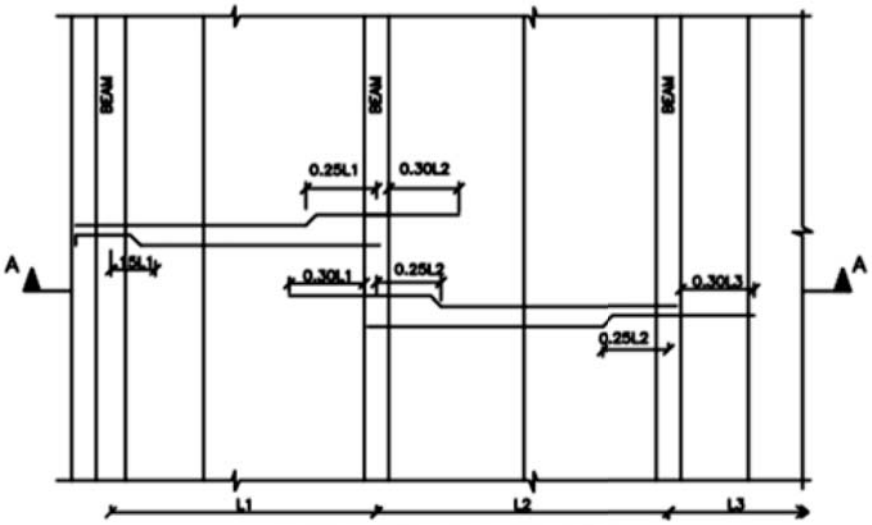
REINFORCEMENT DETAILING

Much attention is generally directed towards analysis and design than towards proper detailing. Experience has indicated that damages occur more due to errors in detailing than due to faulty calculations.

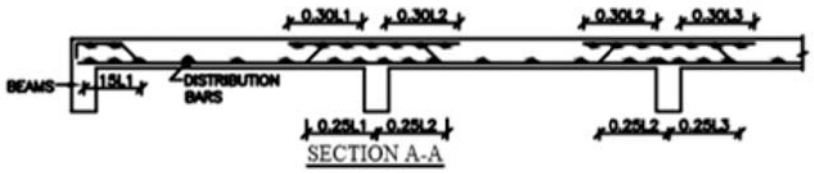
Detailing is as important as design since proper detailing of engineering designs is an essential link in the planning and engineering process as some of the most devasting collapses in history have been caused by defective DETAILING

Slabs

One way Slab



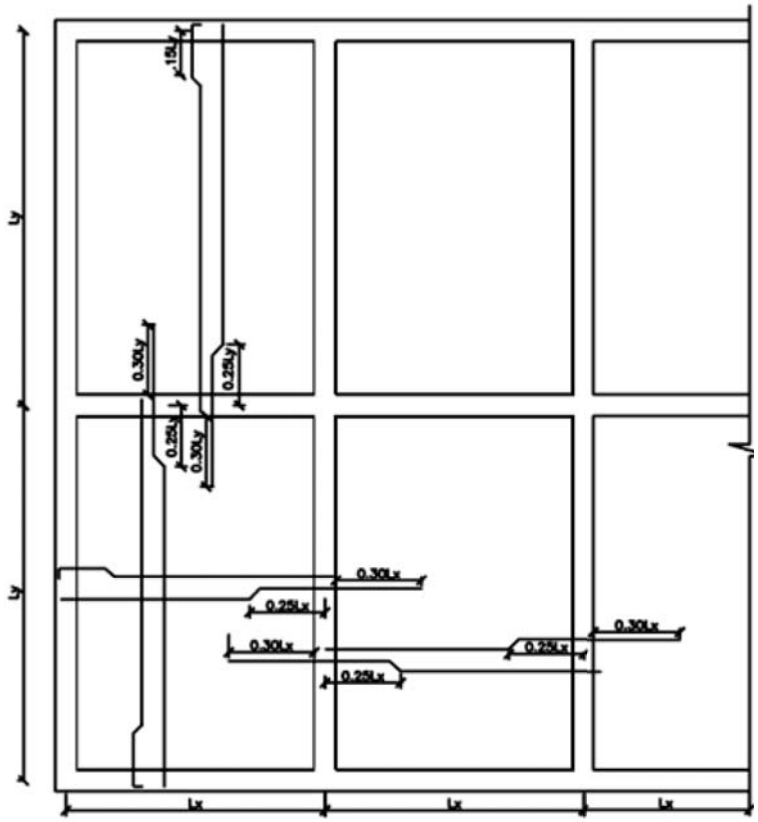
PLAN OF ONE WAY SLAB PANELS



SECTION A-A

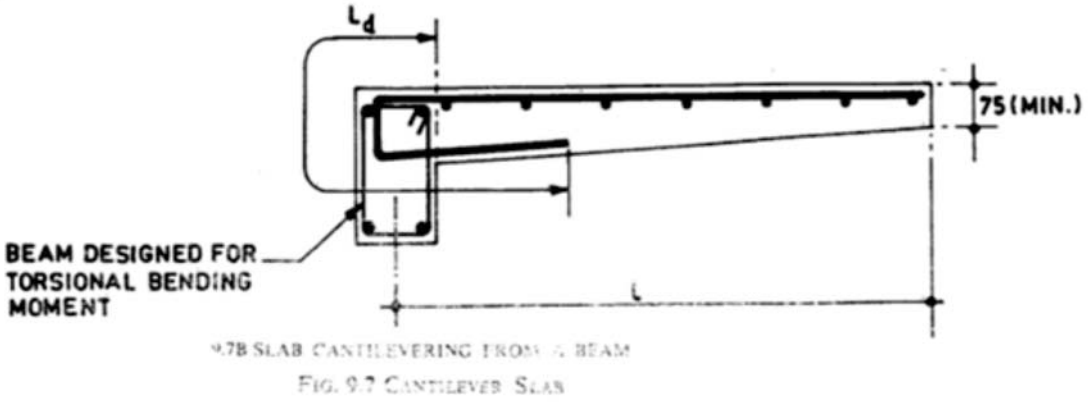
Simplified Curtailment Rule for One way Slab

Two way Slab



Simplified Curtailment Rule forTwo way Slab

Cantilever Slab



9.7B SLAB CANTILEVERING FROM A BEAM

FIG. 9.7 CANTILEVER SLAB

Cantilever Slab from Edge Beam at support

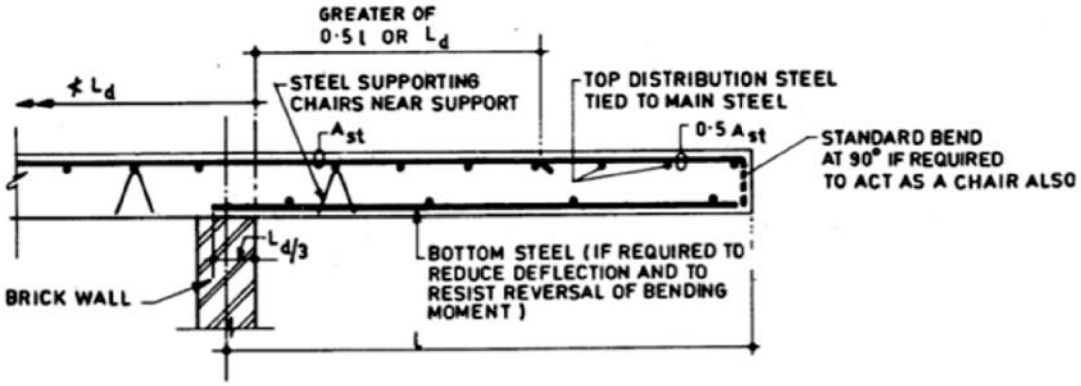
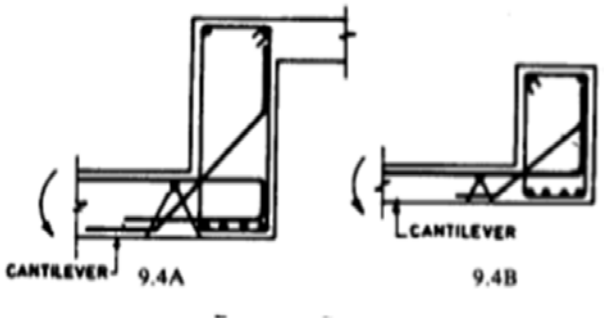
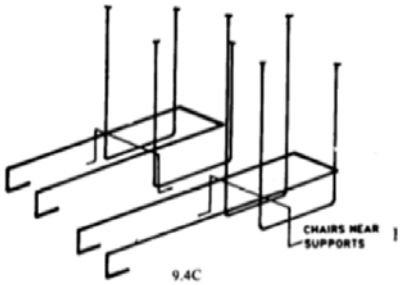
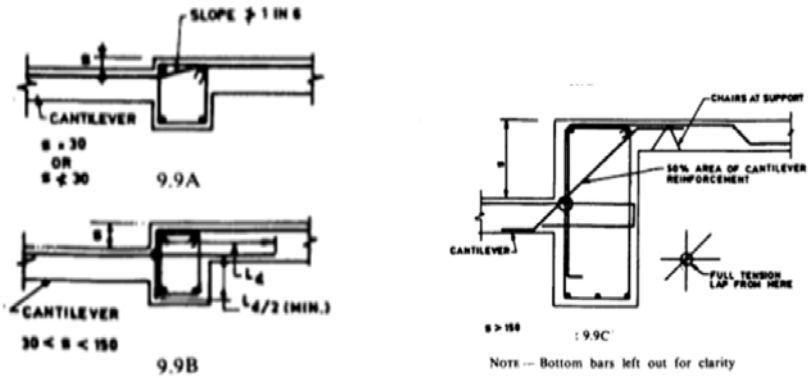


Fig Cantilever Slab continuous over a brick wall

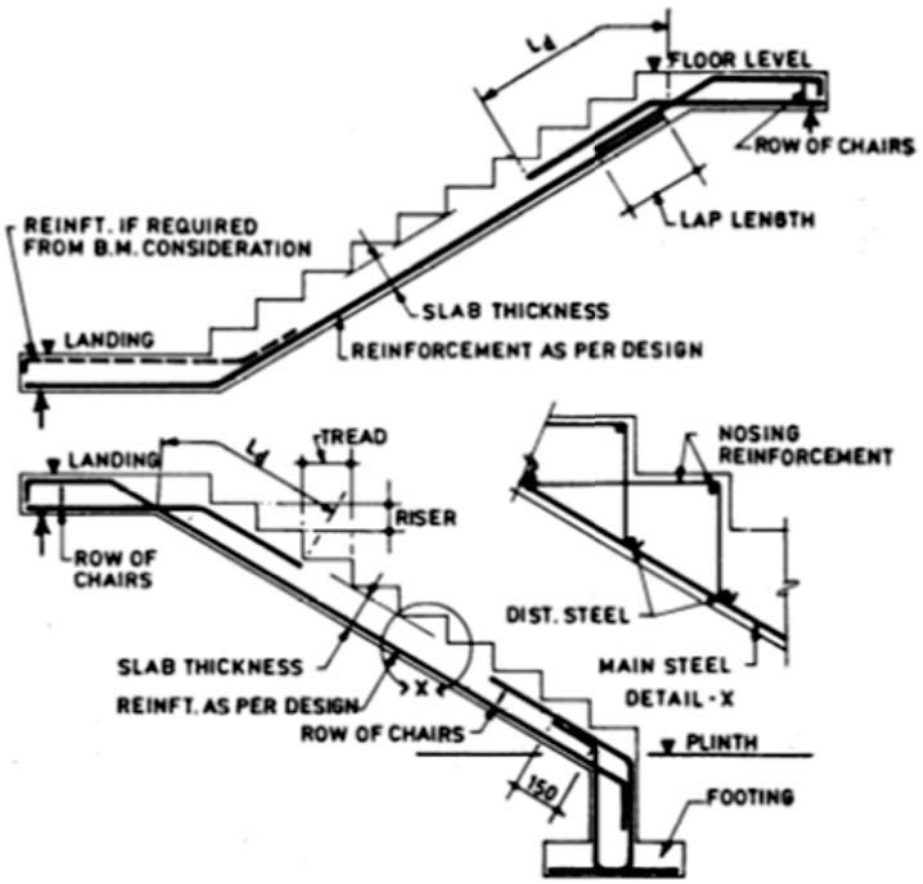


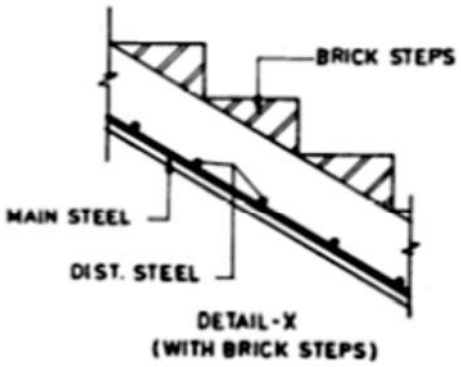




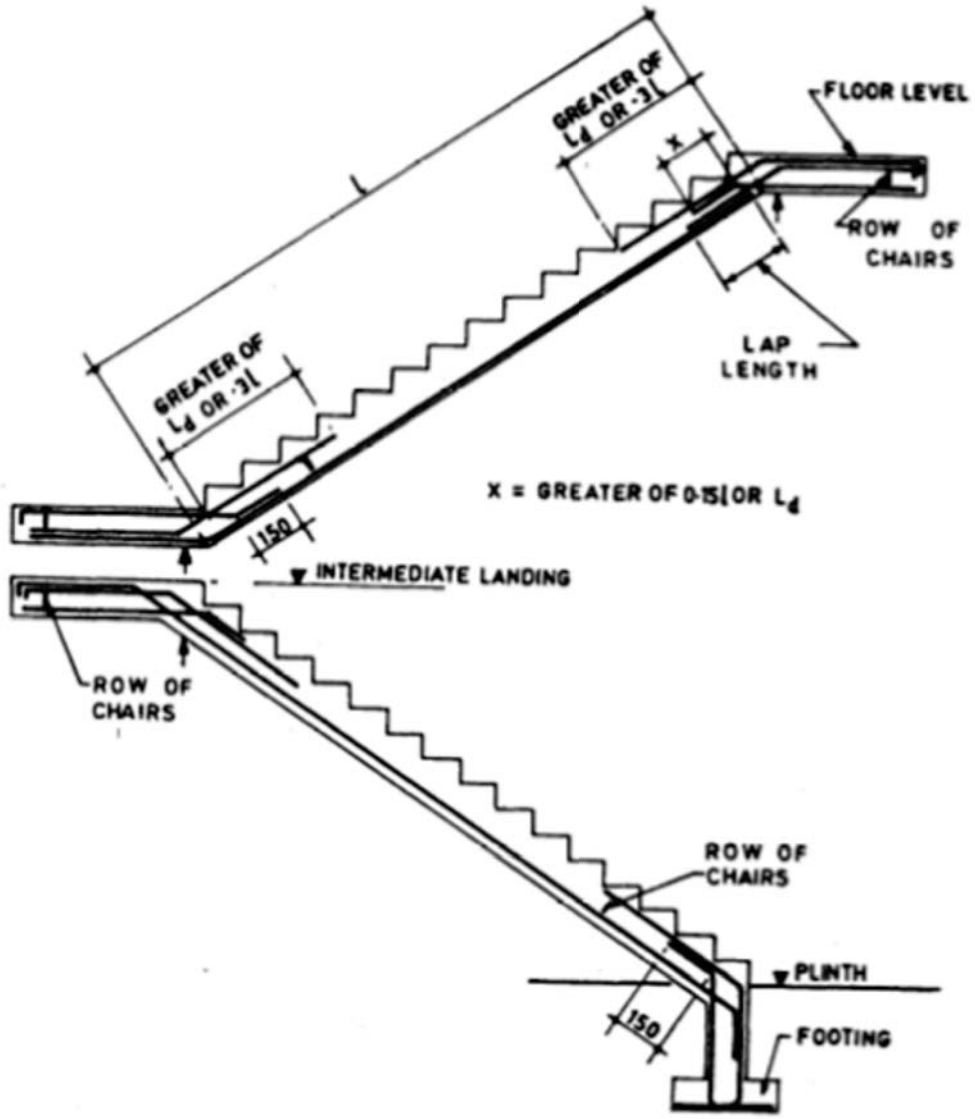
Cantilever Slabs at various levels of Beams

Staircase detailing



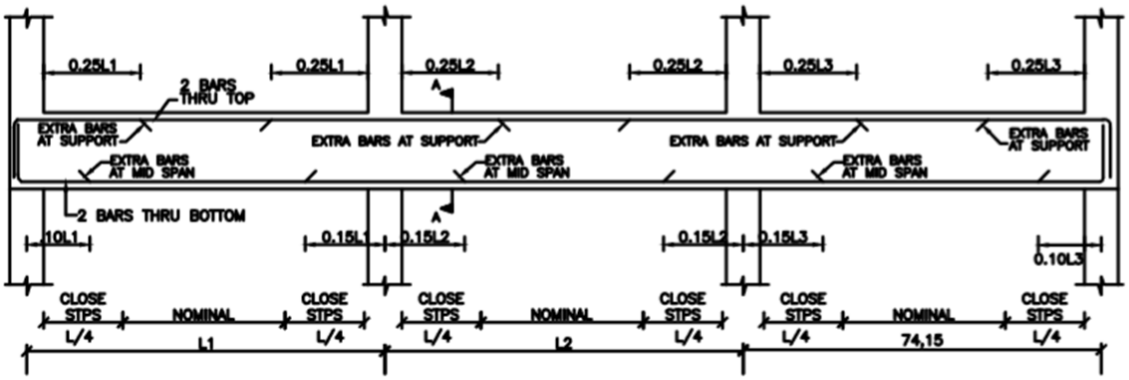


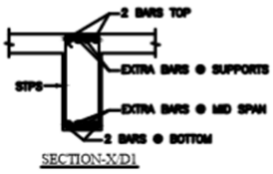
Stairs supported at Ends of Landings



Stairs supported at Ends of Flights

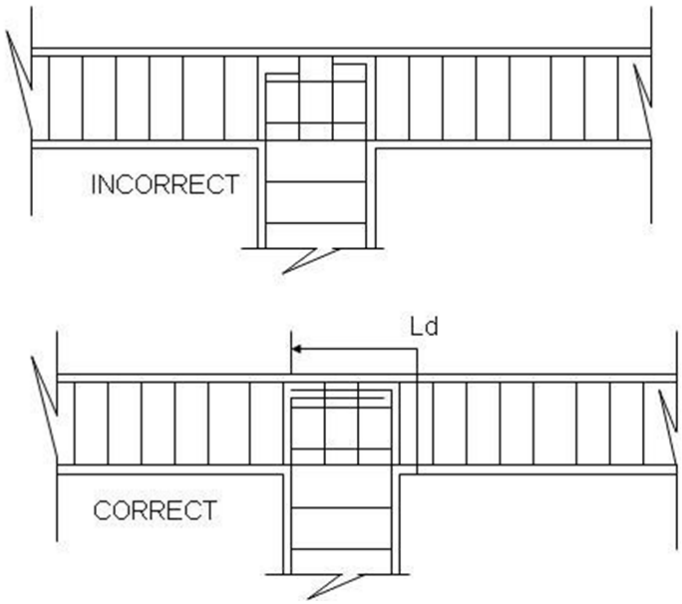
Beams

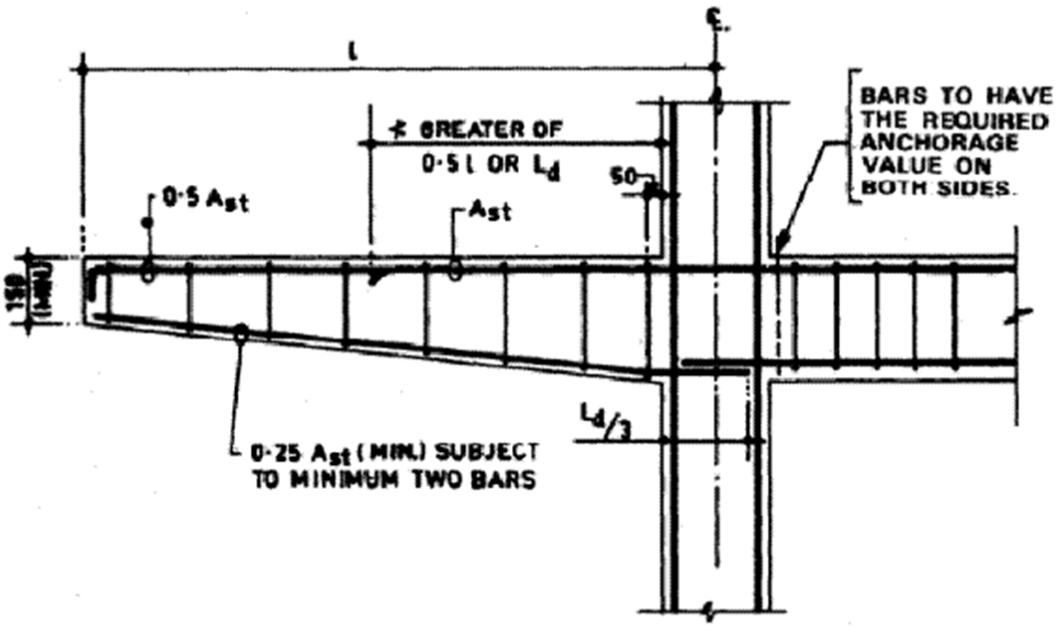




Simplified Curtailment Rule for Continuous Beam

TERMINATION OF COLUMN BARS INSIDE BEAM

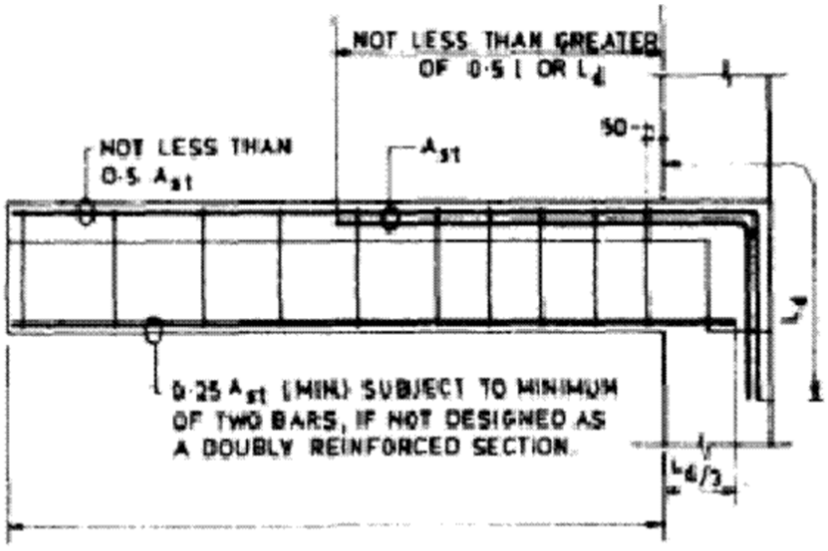




8.17B CANTILEVER BEAM PROJECTING FROM A BEAM OVER A COLUMN

FIG. 8.17 SIMPLIFIED CURTAILMENT RULES FOR A CANTILEVER BEAM

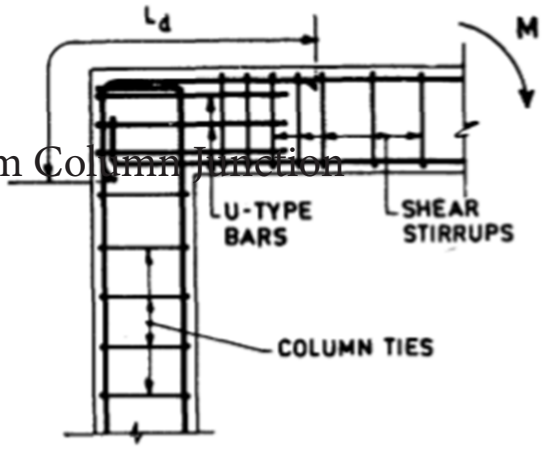
Cantilever Beam Projecting from a beam over a column



8.17A CANTILEVER BEAM PROJECTING FROM A COLUMN

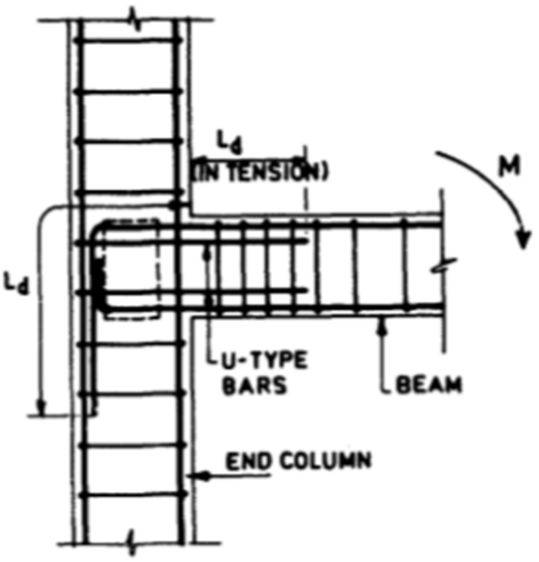
Fig Cantilever Beam Projecting from a column

Beam Column Junction



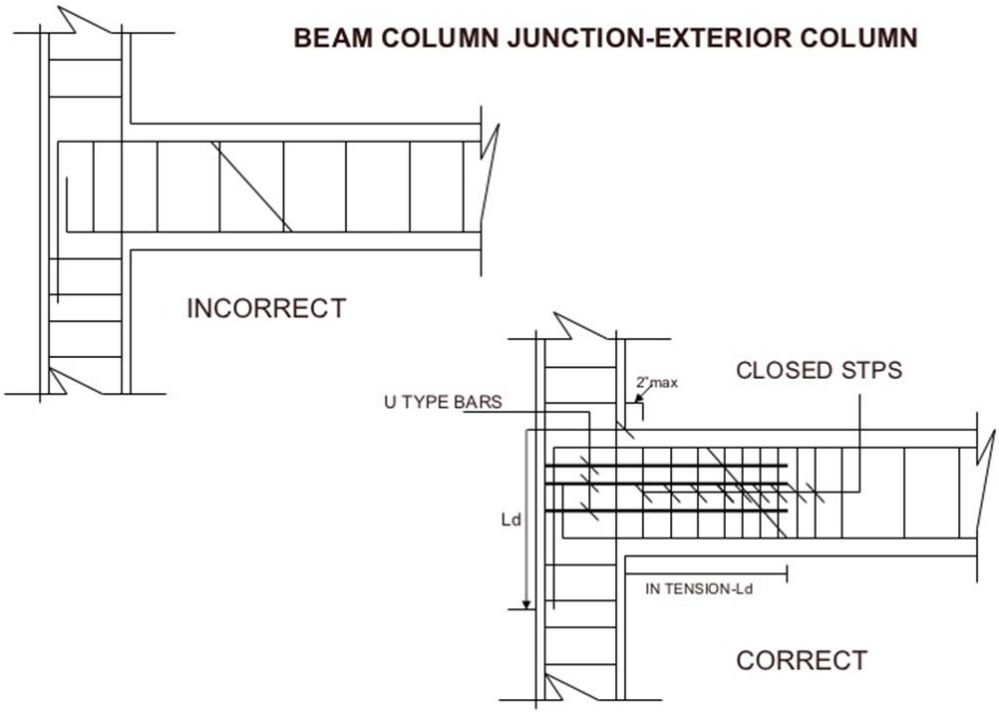
7.14A FIXED END JOINT IN A COLUMN

Beam Column Junction

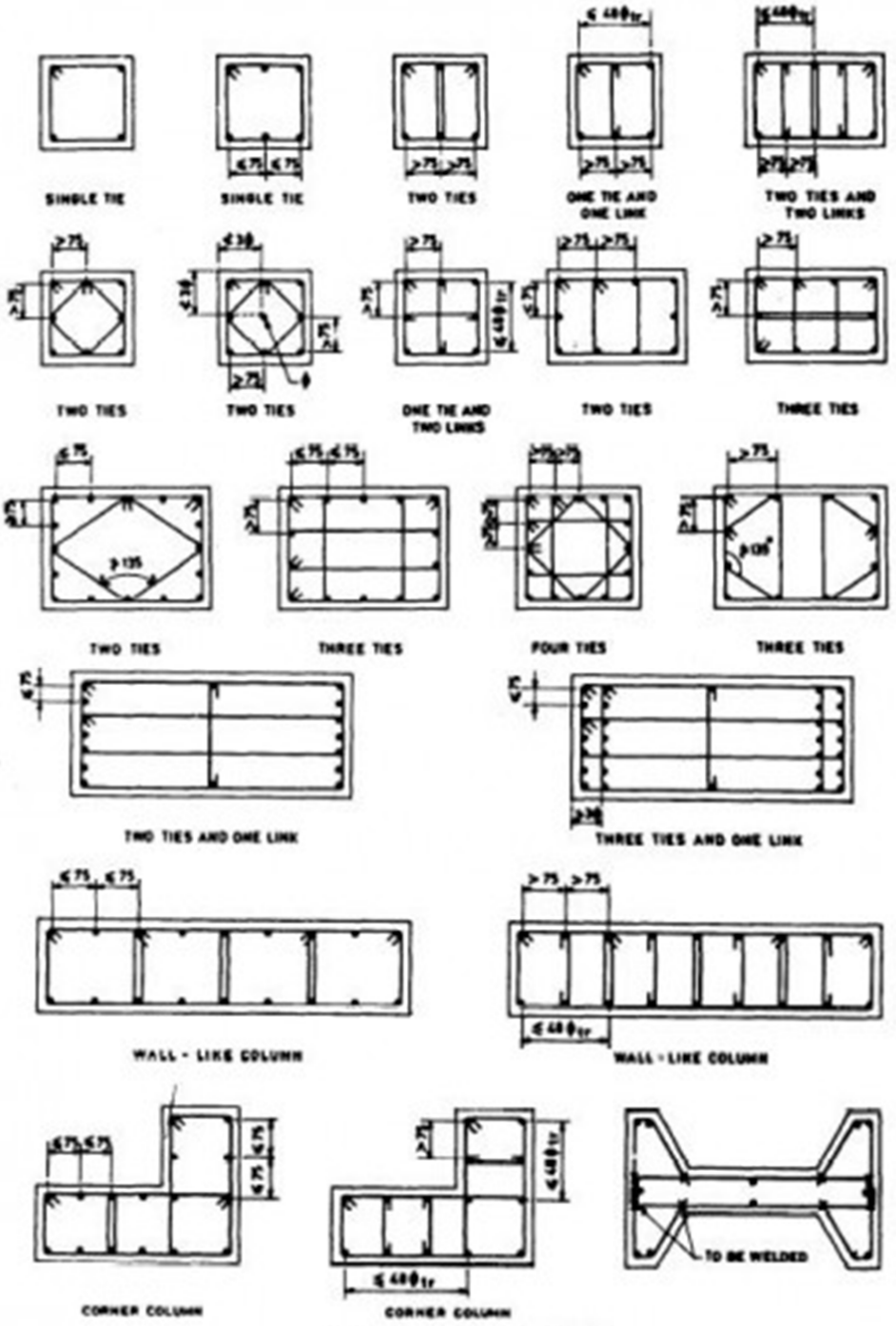


NOTE

In general, it is advisable to use U-bars at the non-continuous ends of beams of depth greater than 600 mm. (clause 7.6/IS456-2000)



Columns



7.5A LATERAL TIES AND LINKS

FIG. 7.5 TYPICAL ARRANGEMENT OF COLUMN TIES *(Continued)*

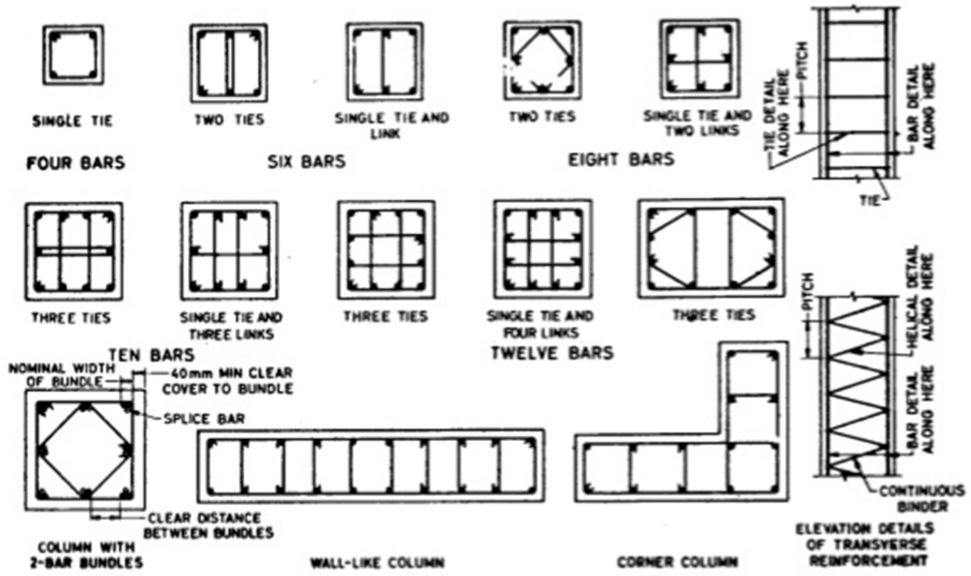


FIG. 7 TYPICAL ARRANGEMENT OF LATERAL TIES AND LINKS IN COLUMNS

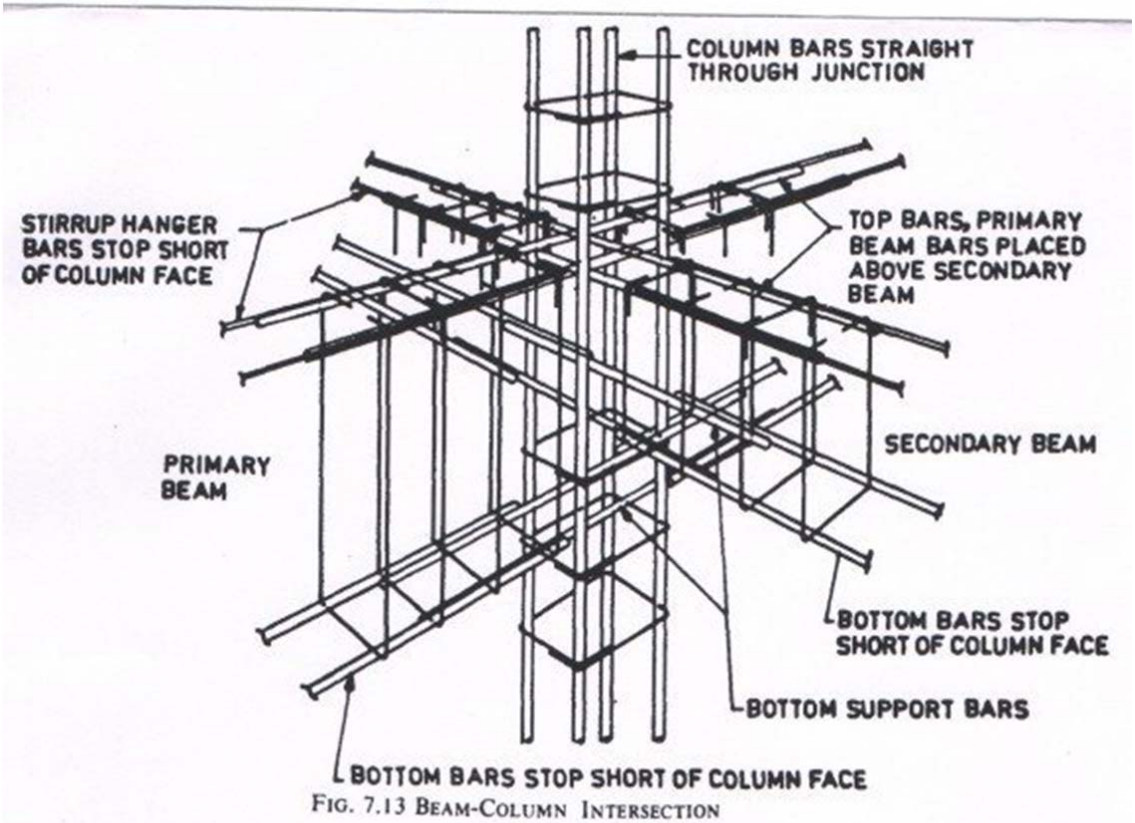
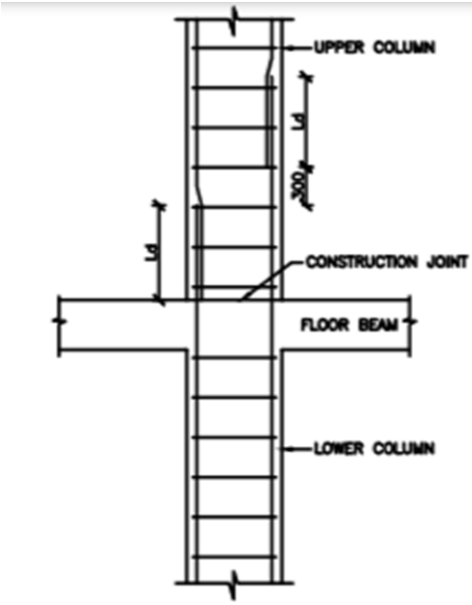
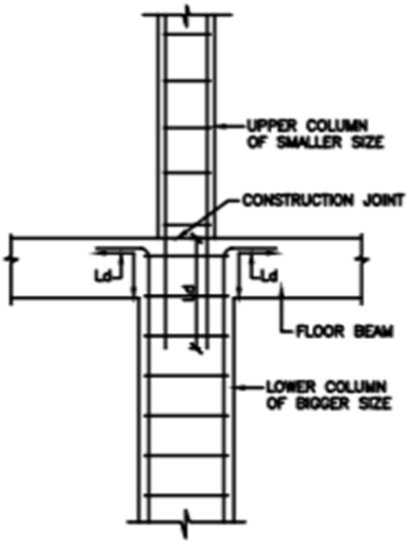


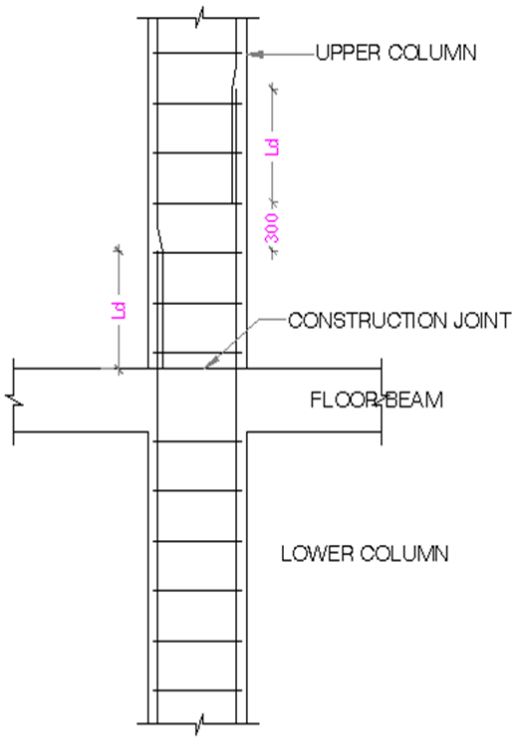
FIG. 7.13 BEAM-COLUMN INTERSECTION



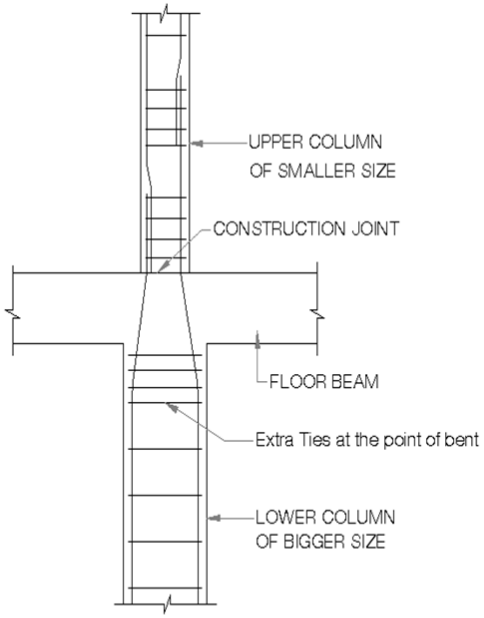
STAGGERED LAPS FOR COLUMN BARS



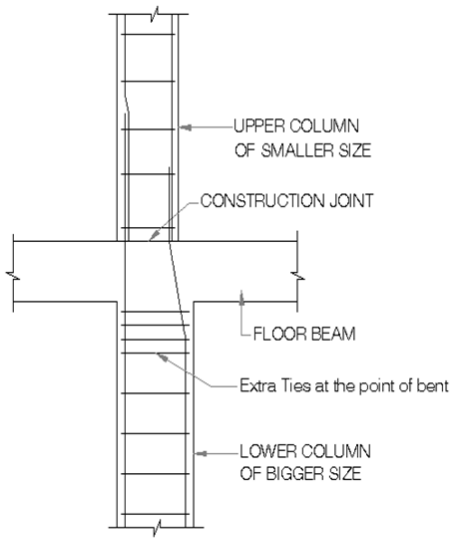
L OF COLUMN BARS WHEN LOWER COLUMN IS BIGGER AND THE UPPER COLUMN IS SMALL



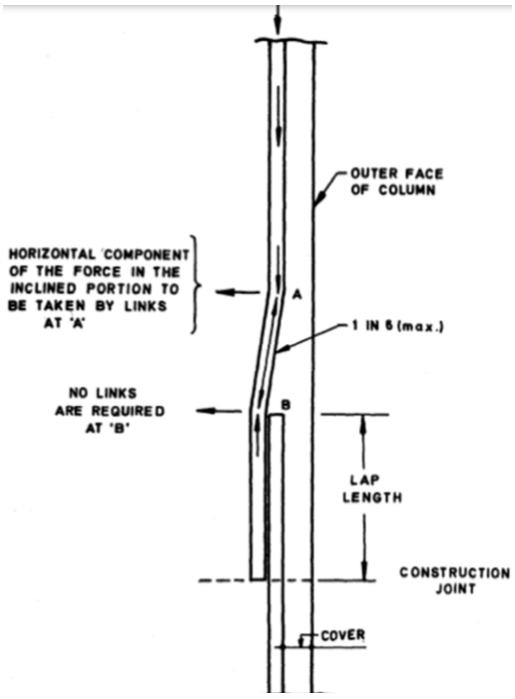
STAGGERED LAPS FOR COLUMN BARS



DETAIL OF COLUMN BARS WHEN LOWER COLUMN IS BIGGER AND THE UPPER COLUMN IS SMALL RECOMMENDED WHEN OFFSET IS < 75mm

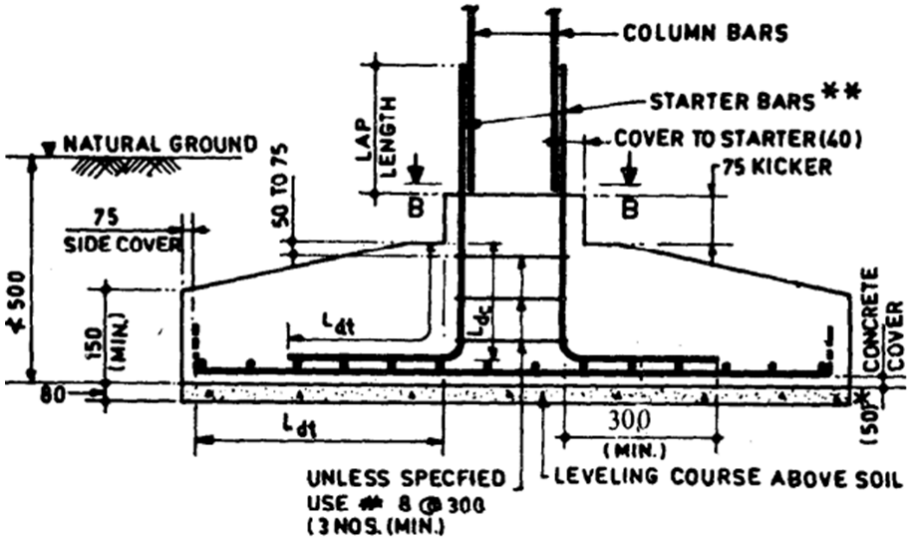


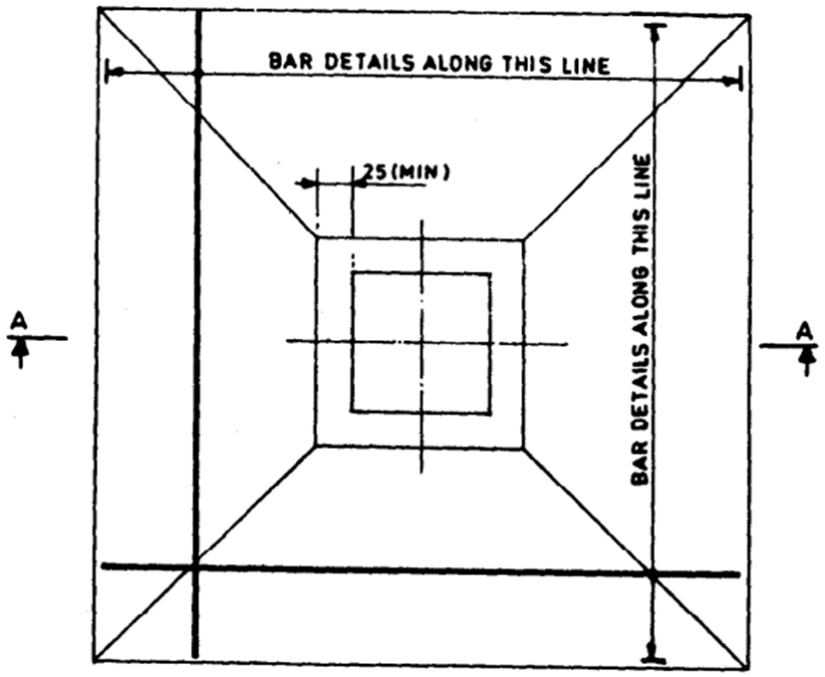
DETAIL OF COLUMN BARS WHEN LOWER COLUMN IS BIGGER AND THE UPPER COLUMN IS SMALL RECOMMENDED WHEN OFFSET IS < 75mm
(OFFSET ON ONESIDE)



Splice with Offset Cranked Bar in a Column

Footings





CHAPTER – V

Guidelines for Earthquake Resistant Structures

1. Guidelines for Planning Earthquake Resistant Structures

- Earthquake causes shaking of the ground. Therefore a building resting on it will experience motion at its base. Even though the base of the building moves with the ground, the roof has a tendency to stay in its original position. But since the walls and columns are connected to it, they drag the roof along with them. The inertia force experienced by the roof is transferred to the ground via the columns, causing forces in columns and in other members.
- The behaviour of a building during earthquakes depends critically on its overall shape, size and geometry, in addition to how the earthquake forces are carried to the ground. Hence, at the planning stage itself, the unfavourable features should be avoided
- In general, buildings with simple geometry in plan have performed well during strong earthquakes. Buildings with re-entrant corners, like those U, V, H and + shaped in plan have sustained significant damage. Many times, the bad effects of these interior corners in the plan of buildings are avoided by making the buildings in two parts. For example, an L-shaped plan can be broken up into two rectangular plan shapes using a separation joint at the junction A building is said to be earthquake-resistant, if it possesses four main attributes, namely,

1) Simple and regular structural configuration,

2) At least a minimum initial lateral stiffness,

3) At least a minimum lateral strength, and

4) Adequate ductility.

- Buildings with simple regular geometry and uniformly distributed mass and stiffness in plan and in elevation, suffer much less damage, than buildings with irregular configurations.

The following simple illustrations show how to plan for earthquake resistant structures

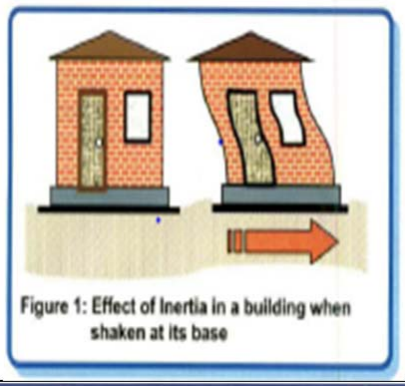


Figure 1: Effect of Inertia in a building when shaken at its base

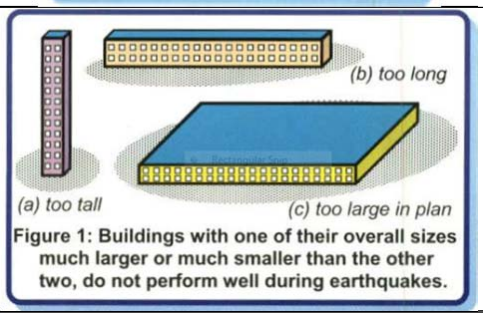


Figure 1: Buildings with one of their overall sizes much larger or much smaller than the other two, do not perform well during earthquakes.

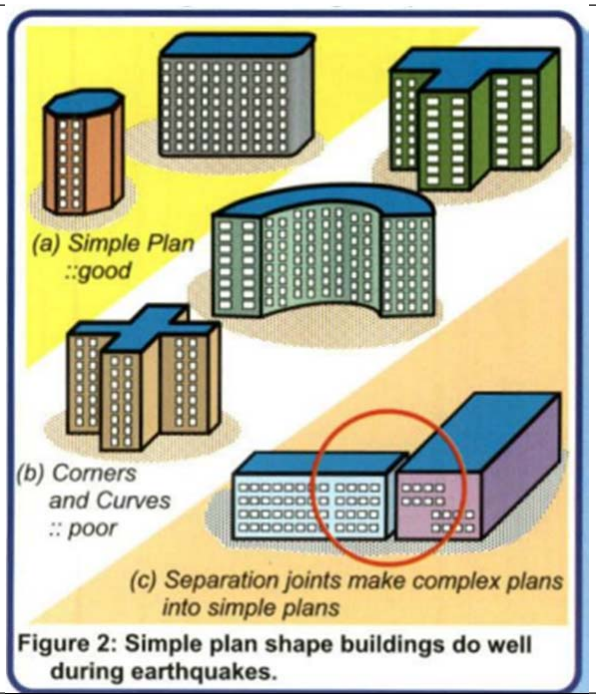


Figure 2: Simple plan shape buildings do well during earthquakes.

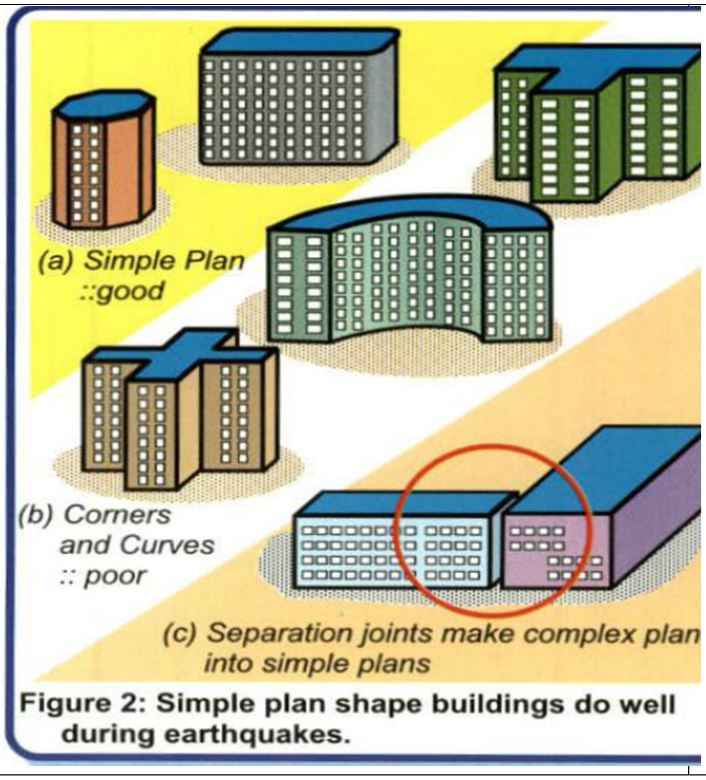


Figure 2: Simple plan shape buildings do well during earthquakes.

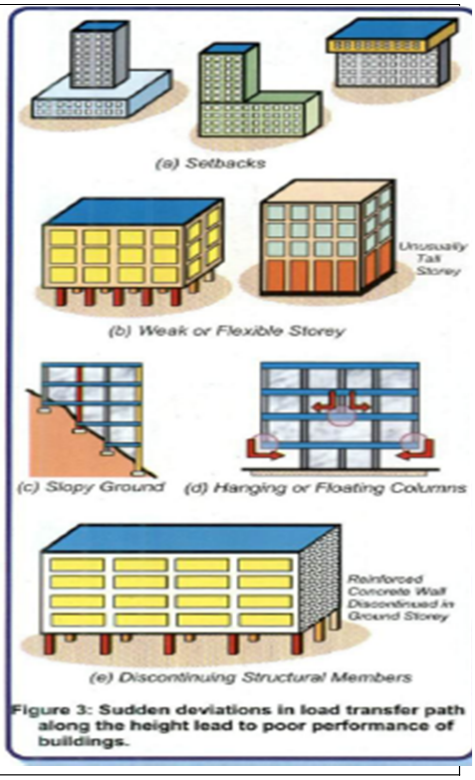


Figure 3: Sudden deviations in load transfer path along the height lead to poor performance of buildings.

2. Guidelines for Earthquake resistant Structural Designs.

IS 1893: (Part 1) 2016 code of practice for EarthquakeResistant Design of Structures deals with the earthquake hazard assessment for earthquake - resistant design of buildings.

IS 13920 :2016, code of practice for Ductile Design and Detail covers the requirements for designing and detailing of members of reinforced concrete (RC) structures designed to resist lateral effects of earthquake shaking, so as to give them adequate stiffness, strength and ductility to resist severe earthquake shaking without collapse.

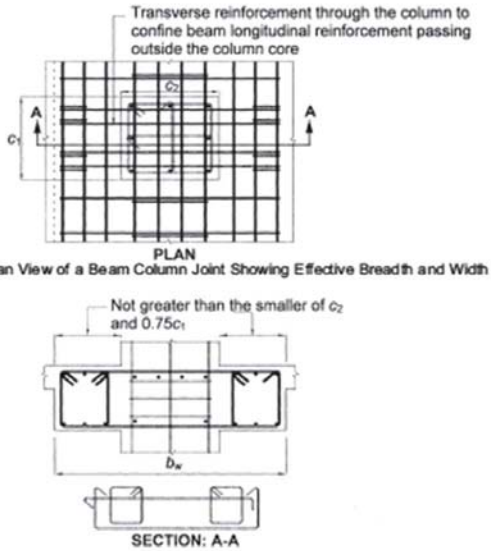
The criteria adopted by codes for fixing the level of design, seismic loading are generally as below

- Structures should be able to resist minor earthquake without damage.
- Structures should be able to resist moderate earthquake without structures damage, but with some non-structural damage.
- Structures should be able to resist major earthquake without collapse but with some structural & non-structural damage.

According to Seismic code IS 1893 -PART1, 2002, it is recommended to adopt 1.5 as important factor for special important factor in design. However a higher value of 1.8 is adopted as per the instructions given in the Guidelines for design and construction of Cyclone/ Tsunami Shelters issued by Government of India – UNDP Disaster risk management programme, Ministry of home affairs -2006.

Due to this higher important factor of 1.8, the buildings constructed for Tsunami shelter sizes of beams and columns were increased. The area of steel provided is arrived for the worst load combinations of seismic and wind loads.

The following illustrations show ductile detailing for reinforcement bars in RCC Constructions.



1A Plan View of a Beam Column Joint Showing Effective Breadth and Width of Joint

1B Maximum Effective Width of Wide Beam and Required Transverse Reinforcement

FIG. 1 BEAM COLUMN JUNCTIONS

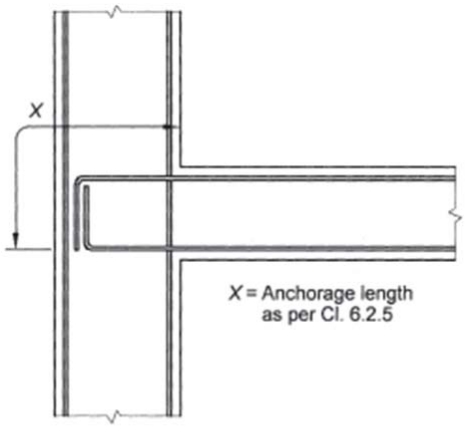


FIG. 2 ANCHORAGE OF LONGITUDINAL BEAM BARS AT EXTERIOR BEAM-COLUMN JOINT

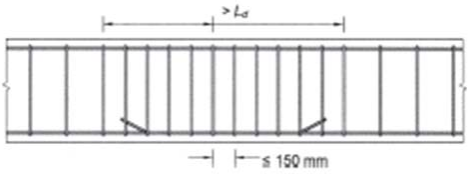


FIG. 3 LAP LENGTH AT LOCATION OF SPLICING OF LONGITUDINAL BARS IN BEAM

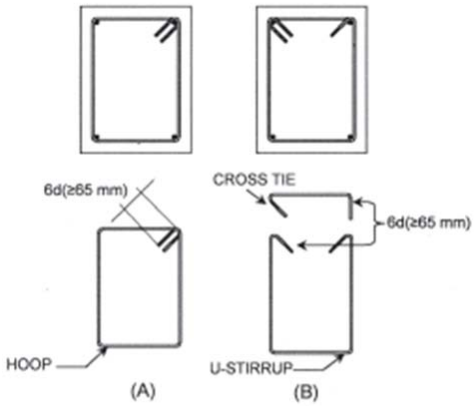


FIG. 4 DETAILS OF TRANSVERSE REINFORCEMENT IN BEAMS

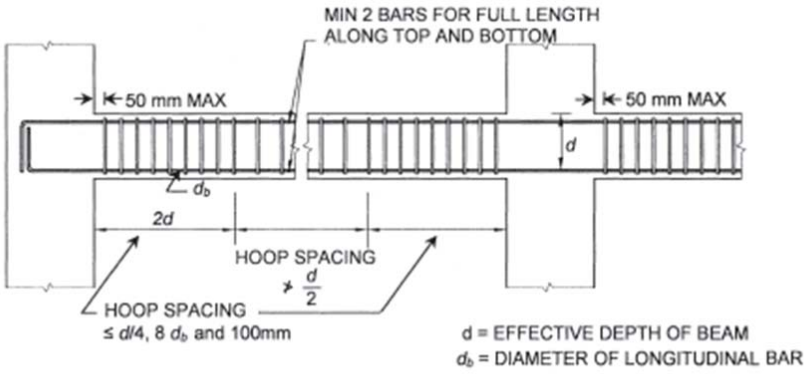


FIG. 6 DETAILS OF TRANSVERSE REINFORCEMENT IN BEAMS

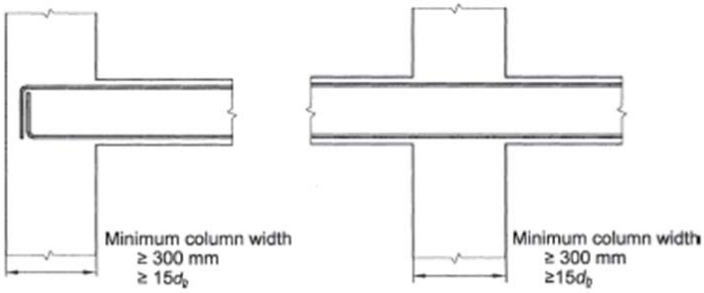


FIG. 7 MINIMUM SIZE OF RC COLUMNS BASED ON DIAMETER OF LARGEST LONGITUDINAL REINFORCEMENT BAR IN BEAMS FRAMING INTO IT

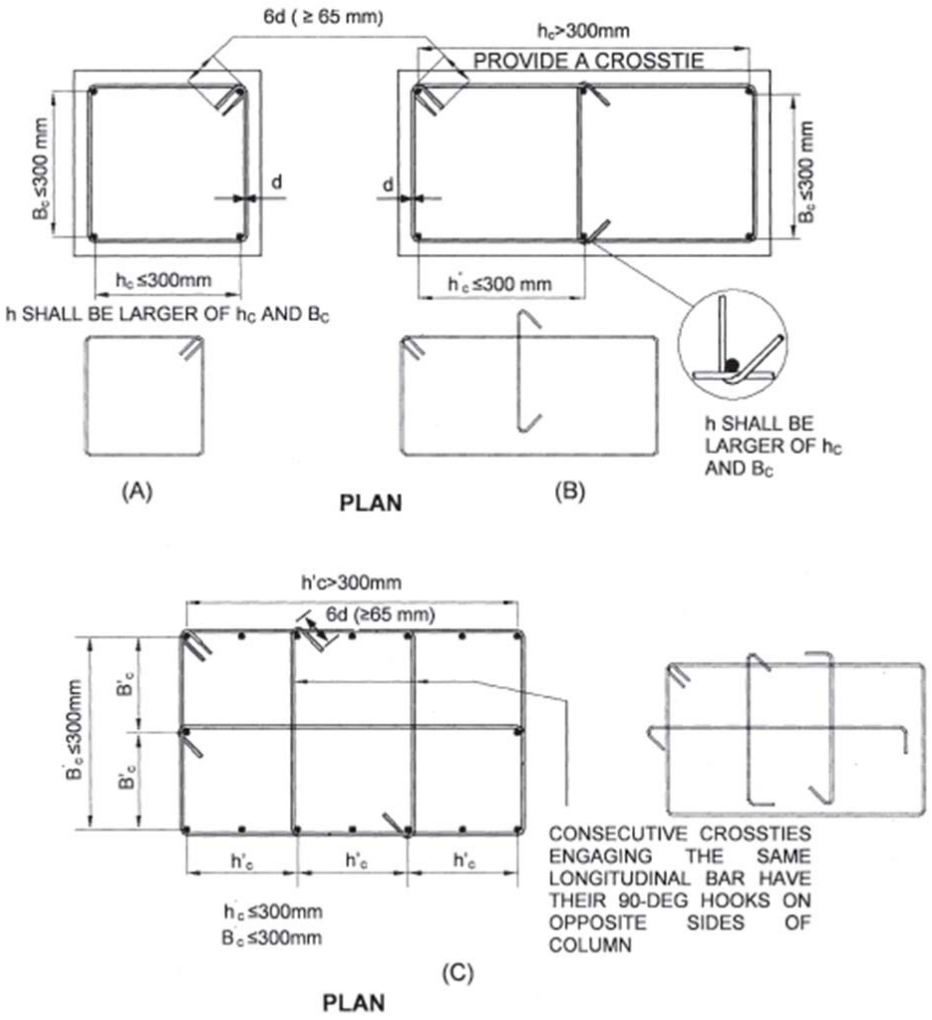


FIG. 10 DETAIL OF TRANSVERSE REINFORCEMENT IN COLUMNS

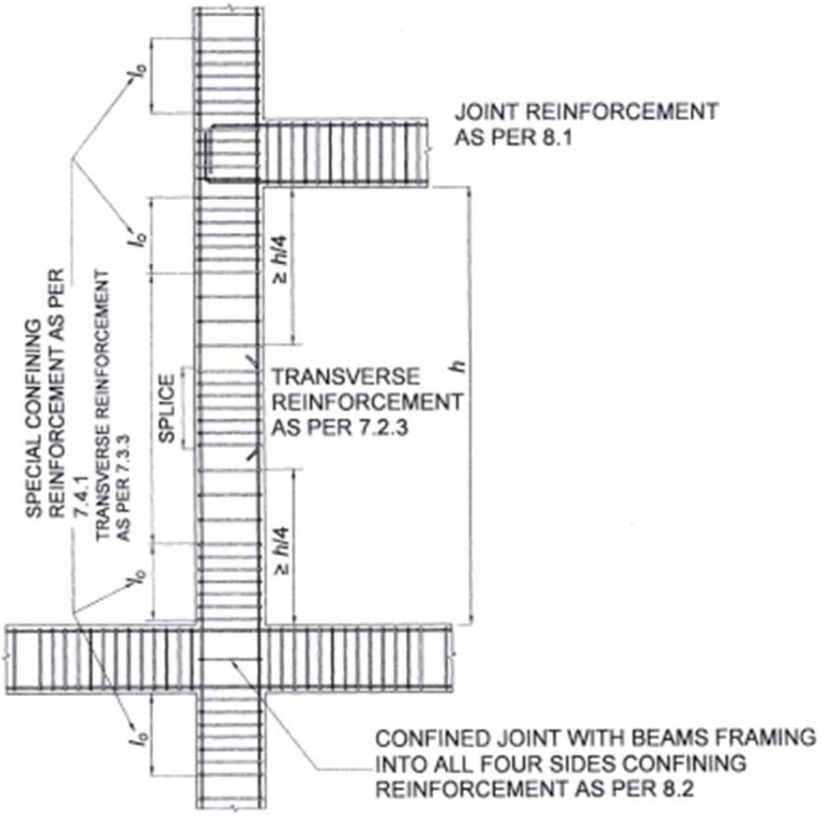


FIG. 12 COLUMN AND JOINT DETAILING

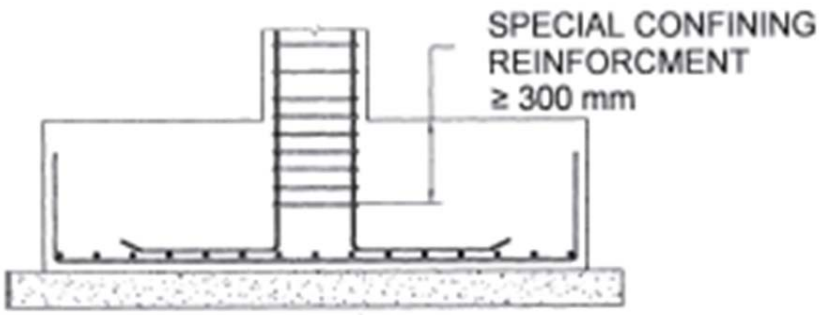


FIG. 13 PROVISION OF SPECIAL CONFINING REINFORCEMENT IN FOOTING

Ductility detailing Provisions for Earthquake Resistant Buildings are summarised in the following figures.

DUCTILE DETAILING AS PER IS13920:2016

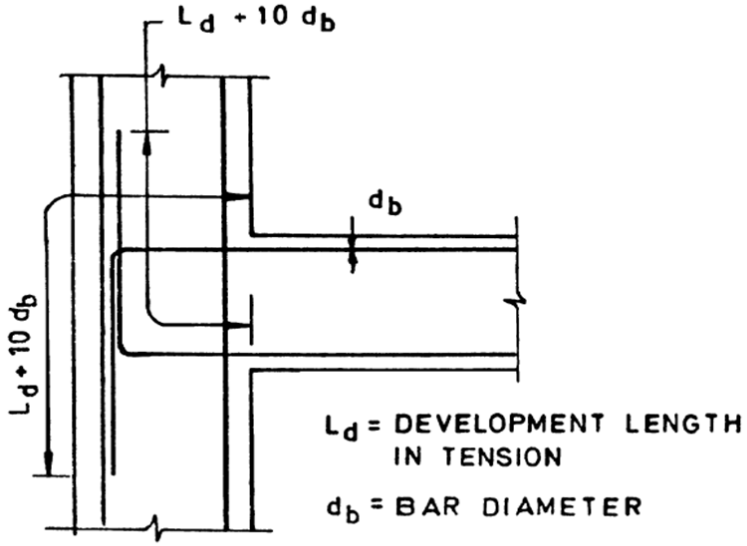
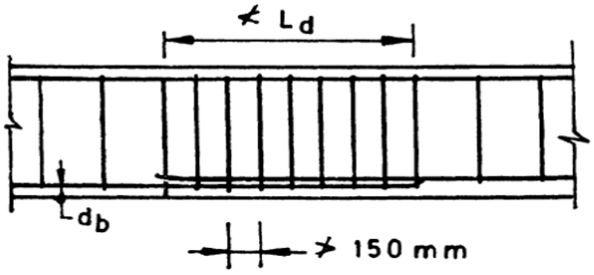


FIG. 1 ANCHORAGE OF BEAM BARS IN AN EXTERNAL JOINT



L_d = DEVELOPMENT LENGTH IN TENSION

d_b = BAR DIAMETER

FIG. 2 LAP, SPLICE IN BEAM

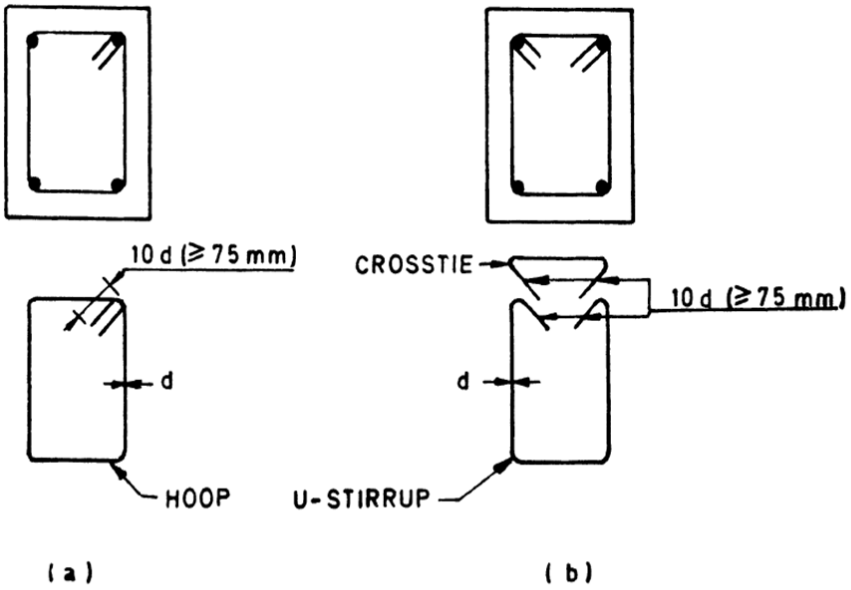


FIG. 3 BEAM WEB REINFORCEMENT

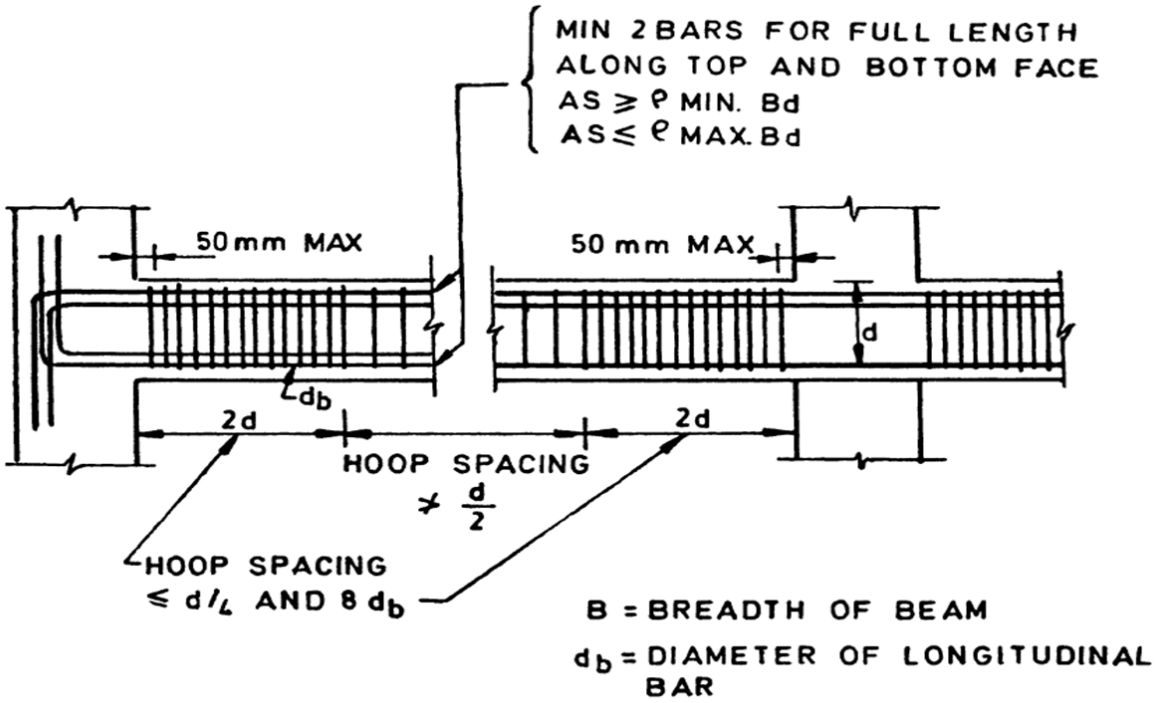


FIG.4 BEAM REINFORCEMENT

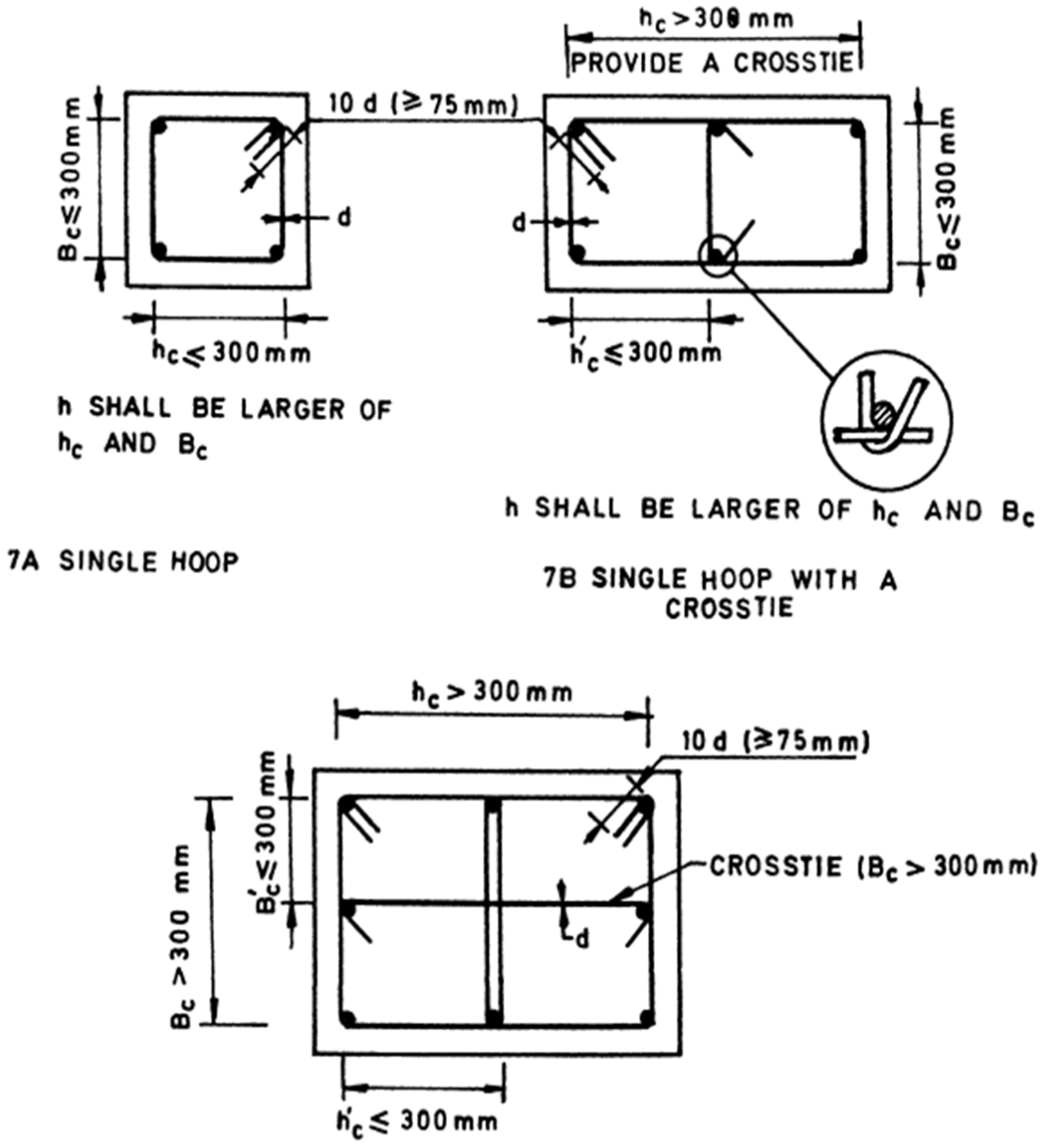
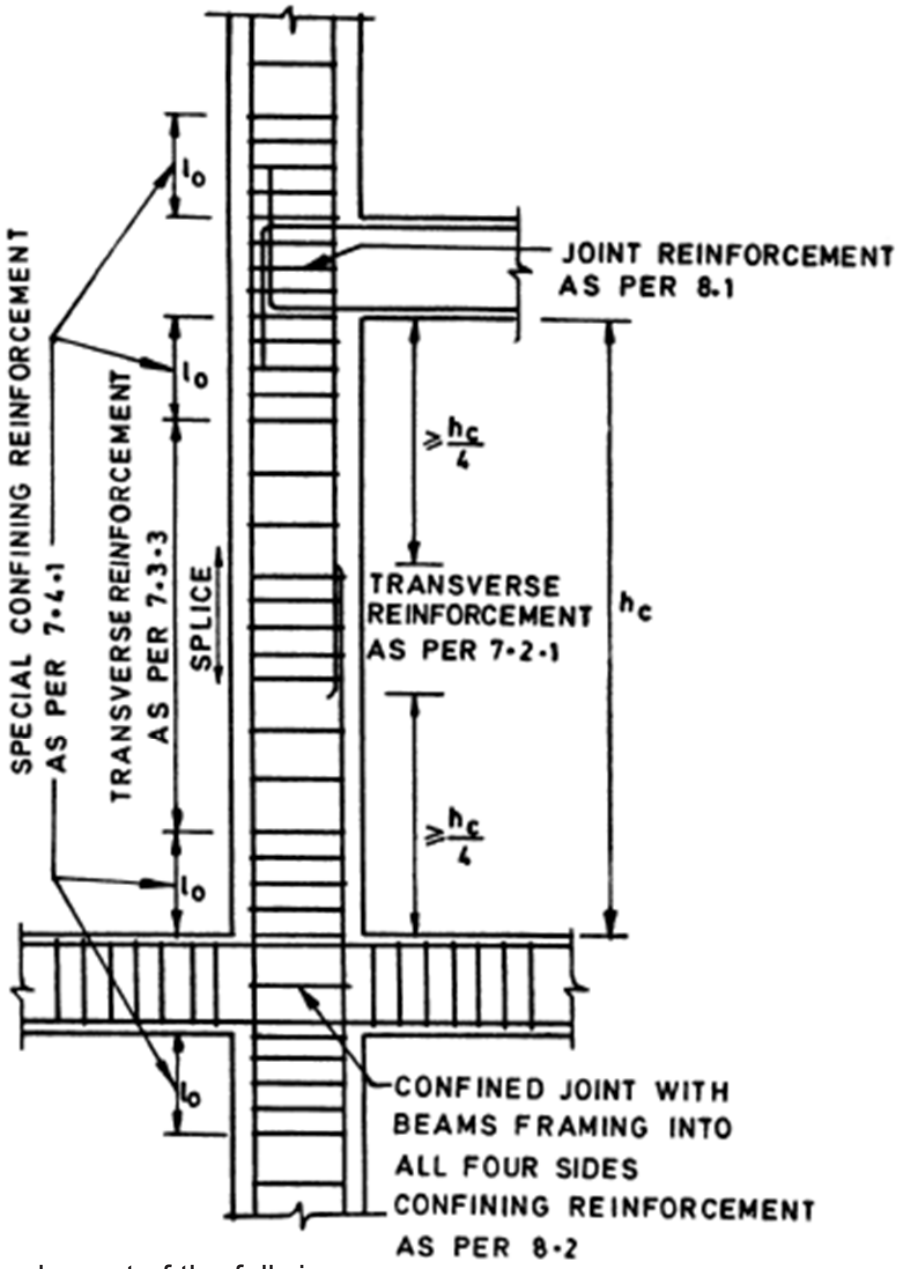


FIG.5 TRANSVERSE REINFORCEMENT IN COLUMN



l_o shall be the largest of the follwing:-

a) 1/6 of clear height of the column,

b) larger lateral dimension of the column, and

c) 450 mm.

Colum Joint detail

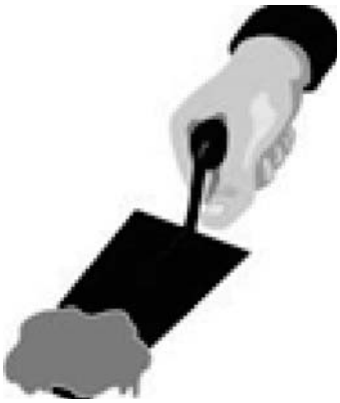
CHAPTER – VI

RAPID TESTING OF CONSTRUCTION MATERIALS AT SITE

INTRODUCTION

All Construction Materials are to be tested for quality before they are actually used in the projects. Though the laboratory tests are accurate, they are very time-consuming and many times it is not possible to evaluate all the consignments.

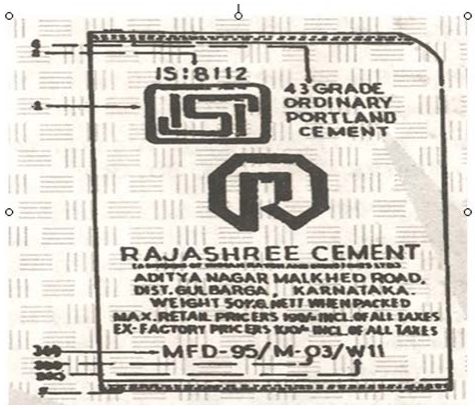
Hence the Engineers at site should be aware of appreciating the quality of construction materials like Cement, Sand, Coarse aggregates, etc by mere visual observation and by conducting very simple site tests.



I - CEMENT

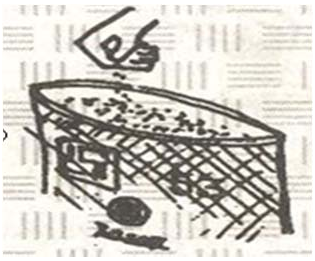
FIELD TESTS TO VERIFY QUALITY OF CEMENT.

1. Date of manufacture must be checked, because aging reduces the strength.



Period of storage	% of 28-days strength
Fresh	100%
3 Months	80%
6 Months	70%
12 Months	60%
24 Months	50%

2. Open the bags – No lumps should be present (Means no setting)
3. Thrust your hand into the cement - There should be cool feeling (means no heat of hydration no setting)
4. Pinch of cement between fingers-It should give smooth feeling (means no setting).



5. Handful of cement thrown on water, should float initially before finally settling.

6. Take 100 gm of cement, make stiff paste, prepare cake with sharp edges, put on glass plate and Immerse in water.

   a. Shape shouldn't be disturbed

   b. It should set and attain strength.

Detection of Adulteration

1. Take a small sample of doubtful cement on a steel plate and heat it thoroughly for 20 minutes on a stove. Adulterated cement will change its colour on heating.

   In genuine variety there will be no change in colour.

However this test cannot detect the addition of pozzolana in cement as it is also produced under high temperatures.

(Max. pozzolana allowed : 35%)

2. To detect adulteration with coal ash take a small quantity of doubtful cement in test tube or a glass tumbler and add water till the container is half full. Shake the container thoroughly and allow it to settle for a few minutes. Cement particles will settle down and ash particles will either be found floating on the surface or held in suspension because of their lightness.

Note: If there is a chance to collect the sample of Flyash used in the cement the fineness and presence of objectionable ash can be checked in the field by mixing the flyash in a bucket half full of water and passing the resulting slurry through an IS sieve 150 microns.No residue shall be left behind on the sieve in the case of a good sample of flyash.

Setting and Hardening action

1. Prepare three small pats each 75mm x 75mm x 25mm in size from the sample given with 28 percent water by weight.

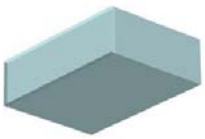
2. Prepare similar number of pats with good quality of cement.

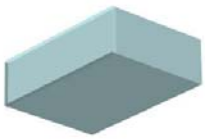
3. Cover the pats with moist cloth for 24 hours

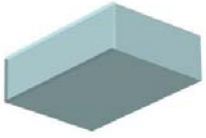
4 Make thumbnail impression or scratch. Good quality cement will resist this impression.

5. If cement doesn't resist this Impression then continue curing it up to 48 hours after which try to break it with pressure of thumb. Bad quality cement will easily break under the pressure.

6. If 48 hours-test show improvement in hardening but does not attain hardness comparable with genuine cement further trail should be made after 72 hours of curing. If the only defect in the cement under test is its slow setting quality, it will become as strong as genuine cement in this third test.







Ascertaining soundness of cement

1. Make a pat of cement 75 mm in diameter and 15 mm thick and cure it with moist cloth for 24 hours and then boil in water for a period of 6 hoursObserve the surface of the pat. If the cement is sound the surface will not develop a pattern of cracks as shown in the figure.

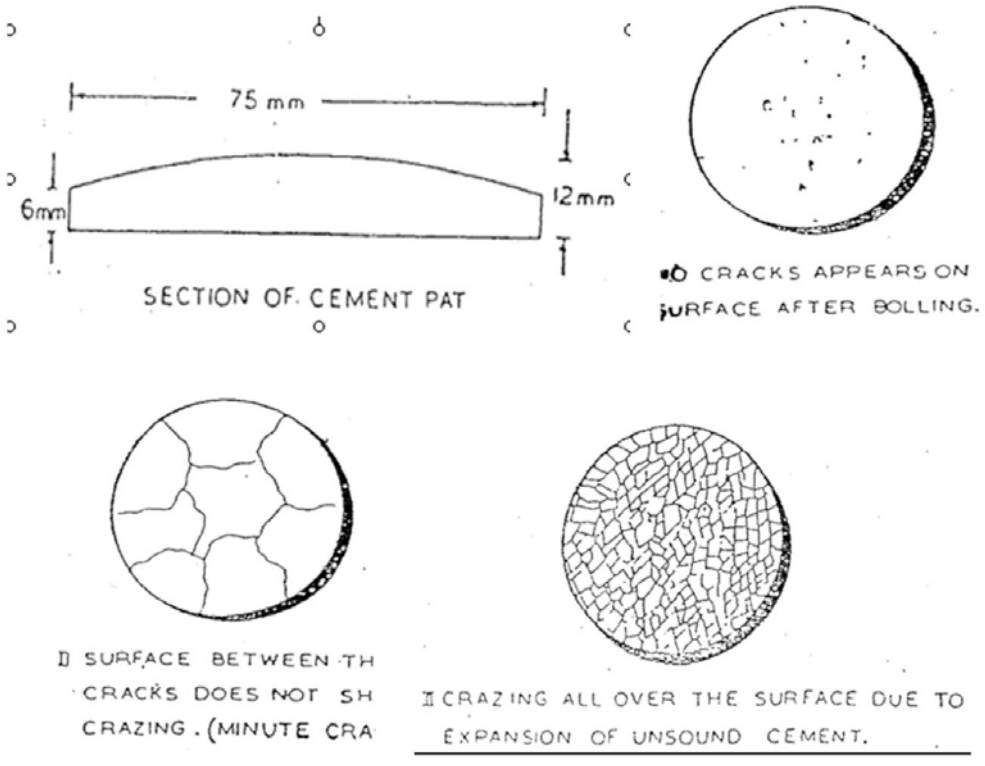
In sound cement cracks are thin and uniformly distributed all over the surface.

Precautions

1. In a test for soundness of cement the cracking of unsound cement should not be confused with the contraction cracks.

2. Contraction cracks develop during boiling where the test pats might have been exposed to heat or drying winds.

Contraction cracks are a few well-defined cracks running from edge to edge as shown in figure and those do not indicate any thing wrong with the sample.



2- SAND

FIELD TESTS FOR SAND

Fine aggregate (Sand) is one which passes through 4.75 mm IS sieve (5-10% oversize permitted by IS : 383-1970)

PROPERTIES OF GOOD SAND

1. It should be chemically inert.
2. It should be clean and coarse. It should be free from any organic or vegetable matter.
3. It should contain sharp, angular grains.
4. It should not contain salts, which attract moisture from the atmosphere.
5. It should be well graded i.e. should contain particles of various sizes in suitable proportions.
6. It should be free from silt and clay.

FIELD TESTS FOR SAND

1. Sand is actually tested and from its taste, presence of salts is known.
2. Sand is taken from a heap and it is rubbed against fingers.

If fingers are stained, it indicates that sand contains silt OR clay

Clay & Silt impurities in Sand

3. A guide to the amount of **clay and silt in sand** can be obtained from the field settling test. An excessive amount recorded in this test will indicate that other more sensitive tests should be made.

The test involves placing about 50 ml of a 1% solution of common salt in water in a 250 ml measuring cylinder. Sand as received, is then added gradually until the level of the top of the sand is at the 100 ml mark and more solution is added to bring the liquid

level to the 150 ml mark. The cylinder is shaken vigorously and the contents allowed to settle for about three hours. The thickness of the silt layer is measured and expressed as a percentage of the height of the sand below the silt layer.

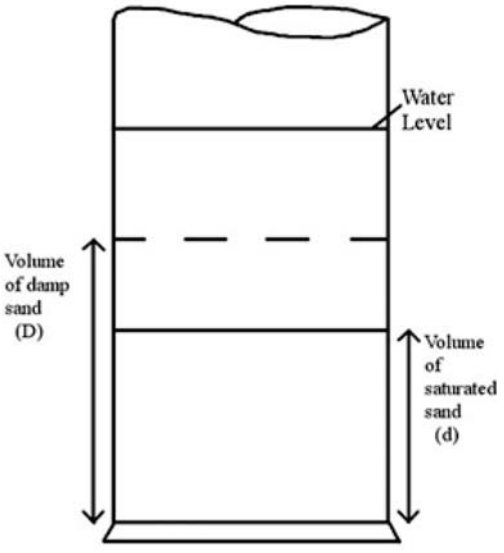
The amount of clay and silt in the sand may be considered acceptable if it does not exceed 8 %. By volume.(3% by weight)





Bulking of Sand

- ✓ Sand containing some moisture shows more volume than actual
- ✓ When dry or saturated, there is no bulking



Bulking of Sand

(IS 2386-Part 3)

Percentage of Bulking =

$$\left\{ \frac{\text{Initial height} - \text{Final height (after flooding)}}{\text{Final height (after flooding)}} \right\} \times 100$$

ORGANIC IMPURITIES IN SAND

4. For detecting the presence of **organic impurities** in sand, solution of sodium hydroxide or **caustic soda** (3% Solution) is added to sand and it is **stirred.**

a. **A colourless** liquid shall indicate clean sand free from organic matter.

b. **A straw** coloured liquid indicates presence of some organic matter but not enough to be objectionable.

c. **A dark colour** means that the sand contains injurious amount and accordingly it is not to be used unless it is washed and re-test shown that it is satisfactory

Colourless / Straw colour
(satisfactory)

Dark brown colour
(objectionable)

3- COARSE AGGREGATES

COARSE AGGREGATES

Coarse Aggregate is one : Which is retained on 4.75 mm IS : sieve
(5-20% passing the sieve are permitted)

PROPERTIES OF GOOD COARSE AGGREGATE

1 Specific Gravity - It should have good crushing strength and Density.

2 Surface Texture – It should be angular and should have sharp edges.

3 Particle Shape – It should not be flaky.

4 Porosity – It should have very low water absorption,

5 Stability- It should be chemically inert.

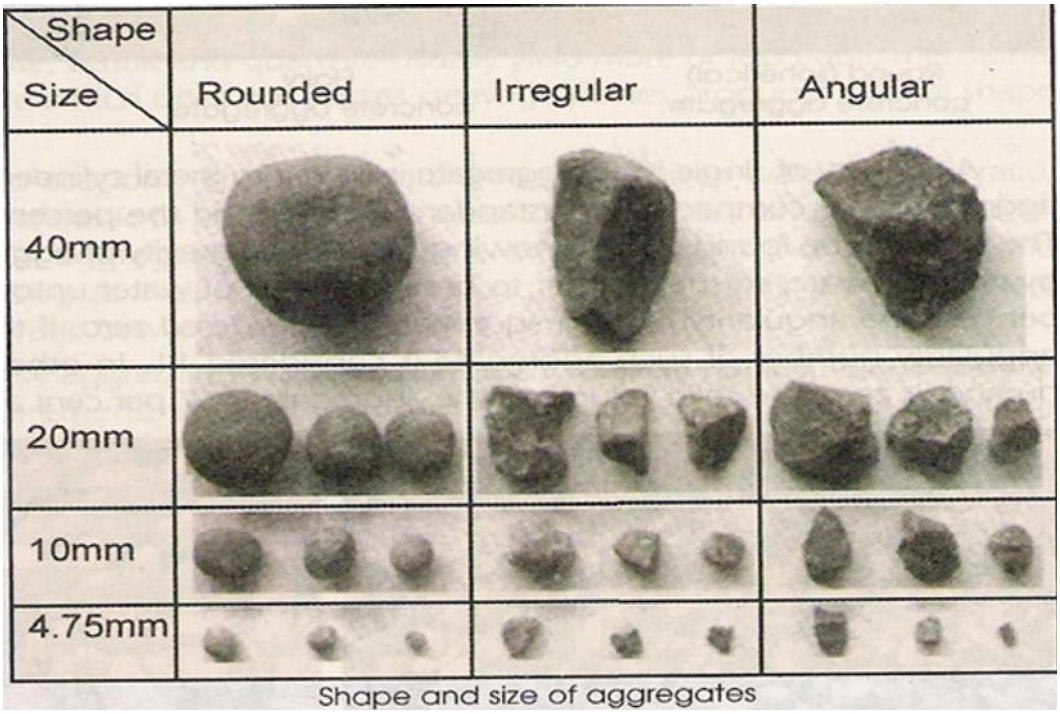
6 Impurities-It should be free from mineral impurities like mica which decay and also clay and silt.

7 Compactness-It should be graded, as then only the voids can be less.

Angular aggregates are superior to rounded aggregates from the following points of view:-

1. Angular aggregates exhibit a better interlocking effect in concrete, which property makes it superior in concrete.

2. The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregates.



Shape and size of aggregates

Gradation requirement of Coarse Aggregates (20 mm)

IS sieve designation	Percentage passing by Weight
40 MM	100
20 MM	95-100
16 MM	-
12.5 MM	-
10 MM	25-55
4.75 MM	0 -10
2.36 MM	-

4 WATER

The water used in making and curing of concrete, mortar and grout shall be free from objectionable quantities of silt, organic matter injurious amounts of oils, acids, salts and other impurities etc. as per I.S. Specification No. 456 – 2000.

Potable water (water fit for drinking) is generally considered fit for mixing.

The PH value of water shall generally be not less than 6.This can be easily found at site with the help of Litmus Paper.

Water suitable for mixing is suitable for curing also. But it should not leave objectionable stain or unsightly deposits on the surface. The presence of tannic acid and iron compounds is objectionable.

Permissible limits for solids when tested in accordance with I.S. 3025 – 1964 shall be as tabulated below.

PERMISSIBLE LIMITS FOR SOLIDS IN WATER

	Maximum permissible limits
1. Organic	200 mg/litre
2. Inorganic	3000 mg/litre
3. Sulphate (as SO4)	400 mg/litre
4. Chlorides (as Cl)	2000mg/litre for plain concrete work 500 mg/litre for RCC work.
5. Suspended matter	2000mg/litre

5 CEMENT MORTAR

CEMENT MORTAR

(i) The cement mortar if unused for more than 30 minutes after addition of water shall be rejected and removed from site.

(ii) The mix proportion of Cement Mortar

The mix proportion of cement: sand can be checked as follows:-

Take about 200 gm of green cement mortar and add 100 ml of water in a measuring jar and shake the contents well and allow the contents to settle. While the sand gets deposited at the bottom, cement shall settle above. From the volumes of each, the approximate proportion of cement and sand can be determined.

(iii) Consistency: Mortar consistency can be checked by the following:

(a) If a small quantity of mortar is dropped from a trowel, the trowel ought to be left perfectly clean.

(b) A little mortar worked gently in the hands should be easily moulded into a ball; on the surface of which water would appear.

(c) When the ball is dropped from a height of half a meter (500 mm) on a hard surface, it must retain its rounded shape.

6 - BRICKS

BRICKS –FIELD TESTS

Basic tests for Bricks:

1. Compressive Strength
2. Water Absorption
3. Efflorescence

1. Compressive Strength

It cannot be determined exactly at field without a Compression testing machine. However, it should not break when dropped from 1 m height on a hard ground. Further when two bricks are struck with each other lightly or when struck with our finger, a clear ringing sound should be produced.

The Minimum Compressive Strength for a Common Burnt Clay Brick is 35 Kg / sq.cm (3.5 N/ sq.mm)

2. Water Absorption

Bricks when soaked in cold water for 24 hours, should not absorb more than 20% by weight for normal bricks.

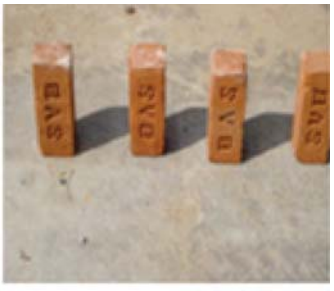
3. Efflorescence

This is due to the presence of soluble salts (such as Sulphates of Sodium and Potassium).

About 3 nos. of bricks are placed in a tray of water about 25mm depth (end side of the Bricks inside water) in a well-ventilated room and they are allowed to absorb the water completely.

When the bricks appeared to be dry, they are examined for efflorescence marks and interpreted as given below:

1) When there is no perceptible deposit efflorescence - Nil
2) 10% exposed area of the bricks covered with a thin deposit - Slight
3) Upto 50% covered by deposit but unaccompanied by powdering or flaking of the surface - Moderate
4) 50% covered by deposit but unaccompanied by powdering or flaking of the surface - Heavy
5) Heavy deposit of Salts accompanied by powdering and / or flaking of the surface – Serious



7 – STEEL REINFORCEMENTS

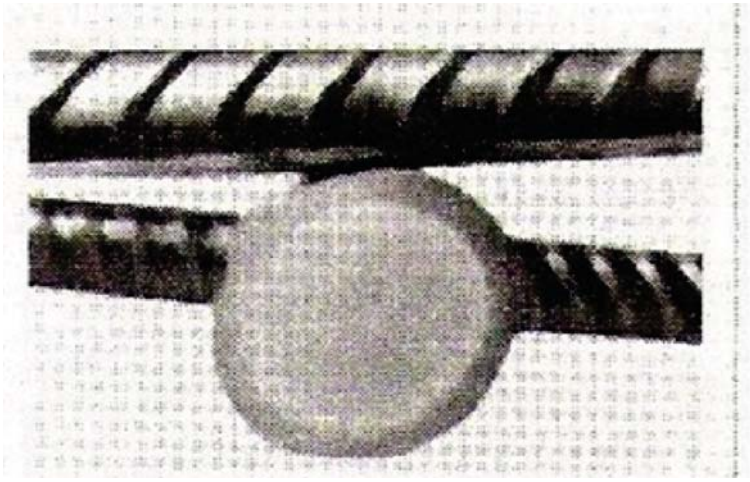
Identification of Good TMT bars

• CUT THE TMT BAR

• POLISH THE CROSS SECTION WITH EMERY PAPER
(If Possible Grind It)

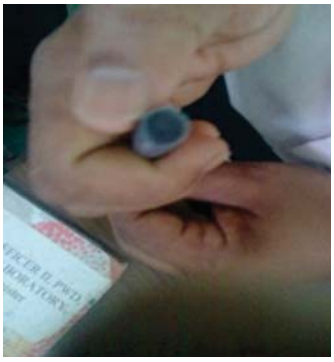
• SOAK IT IN NITROL SOLUTION (if possible)
(5% NITRIC ACID, 95% ETHYL ALCOHOL)

UNIFORM TEMPERED MORTENSITE PERIPHERY & INNER SOFTER CORE INDICATE A GOOD TMT BAR



Identification of Good TMT bars-Illustration

POLISH THE CROSS SECTION WITH EMERY PAPER

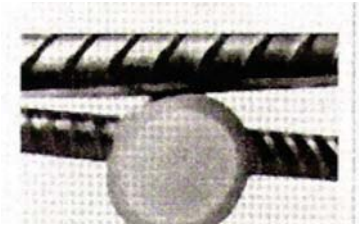

SOAKING IN NITROL SOLUTION

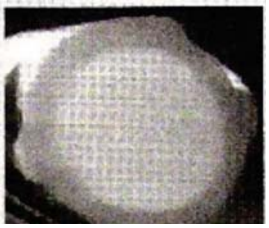
(5% NITRIC ACID, 95% METHYL / ETHYL ALCOHOL)


UNIFORM TEMPERED MORTENSITE PERIPHERY & INNER SOFTER CORE
- GOOD TMT

Good Quality and Fake TMT Bars

UNIFORM TEMPERED MORTENSITE PERIPHERY & INNER SOFTER CORE

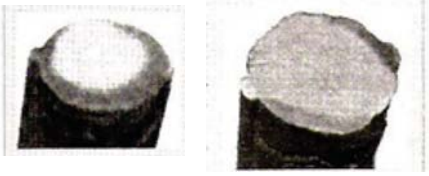




*** FOR GOOD TMT, HARDENED PERIPHERY WILL BE 15 % TO 30% (max) of cross section area.**

HIGHLY OVER QUENCHED BAR HARDENED PERIPHERY IS 60% OF CROSS SECTION

* UNDER QUENCHED BAR HARDENED PERIPHERY IS ONLY 10% OF CROSS SECTION



NON UNIFORM QUENCHED BAR

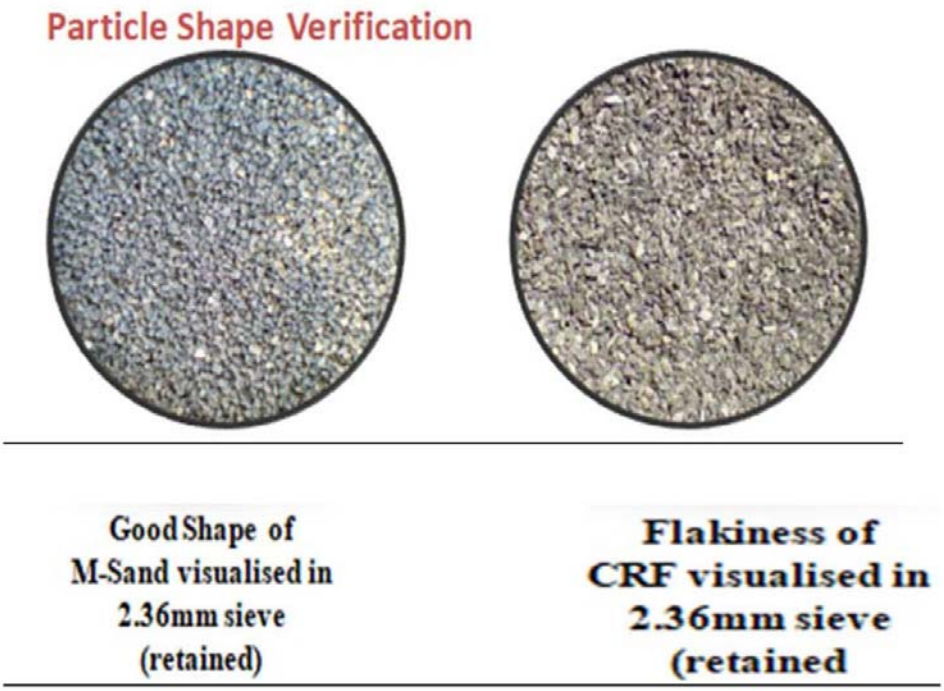
CHAPTER - VII

Crushed Stone Sand (CS-Sand)

- Alternate material to River sand

In recent years, considerable emphasis has been made by the experts in the construction industry to use Manufactured Sand (M-Sand) as an alternative to River Sand as the later is getting exhausted very rapidly. It has also been proved technically worldwide that Good quality M-sand is a suitable alternative construction material to River sand.

However, there has been general reluctance to use the M-Sand in construction works mainly due to lack of availability and supply of genuine M-Sand. It has been noticed that Quarry Dust which contains Flaky particles and higher percentage of Micro fines (particles less than 75 mcron) were supplied in the name of M-Sand. Since these properties affect the quality of concrete, Construction Industry tried to avoid the usage of M-Sand in general.



Hence, to bring awareness about genuine M-Sand and promote to use of the same as an alternate fine aggregates to River Sand, circulars were issued by the Public works Department explaining the manufacturing process of good quality M-Sand and the methods of identifying, procuring and using them for construction purposes.

Circulars attached in the following pages helps to understand the facts on M sand and get rid of the myths.

PUBLIC WORKS DEPARTMENT

BUILDINGS

**OFFICE OF THE ENGINEER-IN-CHIEF (BUILDINGS),
CHIEF ENGINEER (BUILDINGS) CHENNAI REGION AND
CHIEF ENGINEER (GENERAL), PWD.,
CHEPAUK, CHENNAI – 5**

Technical Circular No. AEE / T10 / 57017 , dated .07.2017

Sub : Building – Crushed Stone Sand (CS-Sand) - Alternate material to River sand – Circular Instructions issued - Regarding

Ref : Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD., Circular No. AEE / T10 / 57017 / 2012, dated 30.08.2012

****

1.0. In recent years, considerable emphasis has been made by the experts in the construction industry to use Manufactured Sand (M-Sand) as River Sand resources are exhausting very rapidly. It has also been proved that Good quality M-sand can be used as an alternative construction material to River sand.

2.0. Though the definition of Manufacturing Sand (M-Sand) as per IS 383:2016 code refers to processed fine aggregates, the Crushed Stone Sand is commercially called as M-sand in the Market.

3.0. In the reference circular cited, PWD permitted to use Crushed Stone Sand hereafter called “CS-Sand” in the construction work as an alternate material to Natural Sand with the condition that it should comply with all the requirements as stipulated by relevant codes of Bureau of Indian Standards.

4.0. However, there has been general reluctance to use the CS-Sand in construction works mainly due to lack of supply of good quality CS-Sand. It has been noticed that Quarry Dust which contains Flaky particles and higher percentage of Micro fines (particles less than 75 micron) is being supplied in the name of CS-Sand and these properties affect the quality of concrete and other works.

5.0. Hence, in continuation of earlier circular instructions issued, to bring awareness about the use of good quality CS-Sand and to promote the use of the CS-Sand an alternate to River Sand, the following further circular instruction are issued in respect of quality checks to be carried out on CS-Sand and the manufacturing process of good quality CS-Sand.

6.0. IS 383:2016 code under clause 3.1.2 defines the crushed sand as, (1) Crushed stone sand - Fine aggregate produced by crushing hard stone. (2) Manufacturing fine aggregate (Manufactured Sand) - Fine aggregate manufactured from other than natural sources, by processing materials, using thermal or other process such as separation, washing, crushing and scrubbing.

Quality checks on Crushed Stone Sand

7.0. Following aspects help to assess the quality of CS-Sand.

- Carrying out Simple field tests for certain parameters.
- Testing at the Laboratories shall be in accordance with IS Bureau of Indian Standards.
- Inspection of CS-Sand production unit to ensure that the unit has the five stage processes established and practiced.

Field Tests on Crushed stone sand

8.0. Keeping in hand the Crushed Stone Sand taken from a heap and just by visual observation and rubbing it in between fingers, excess presence of quarry dust , flakiness , gradation , texture of crushed stone sand etc., is verified and quality can be ensured based on the experience.

Testing of CS-Sand by “visual observation” and “rubbing with hand” to assess the presence of Quarry dust

Shape test by visual observation

9.0. Particles retained on 4.75mm and 2.36 mm can be verified visually for the particle shape. Additionally, an image taken with the help of Mobile camera that has resolution of 8 MP and more can be zoomed to verify the shape.

Particle Size Distribution by Sieve Analysis

10.0. Sieve Analysis can be carried out at site with the set of sieves as stipulated by BIS to find out the particle size distribution of CS-Sand across various size fractions.

Good quality CS-Sand (2.36mm) - Cubical

River Sand (2.36mm) - Cubical

Poor Quality CS-Sand with Flaky Particles

Good Quality CS-Sand

VSI Crushed Sand - Cubical - Good Quality

JAW Crushed Sand - Flaky - Poor Quality

Particles less than 75 micron (Micro fines)

11.0. This test is done by “Wet Sieving” CS-Sand sample through 75 micron sieve through which the presence of Micro fines can be measured. Though IS 383:2016 accepts 15% as upper limit for presence of Micro fines, according to Industry experts it is advisable to limit this upper value to 7%.

Cube test for compressive strength

12.0. After the use of CS-Sand, to test the compressive strength of concrete, the specimen of required numbers of standard cube of (150 mm x 150 mm x 150 mm) have to be casted and cured in water and tested for 3, 7 and 28 days and test results should comply the stipulated requirements of Bureau Indian Standards.

Laboratory Tests on CS-Sand

13.0. CS-Sand should adhere to the highest standards and must undergo the following quality tests

1. Sieve analysis
2. Specific gravity
3. Water absorption
4. Bulk density (loose and compact)
5. Alkali aggregate reaction
6. Soundness
7. Deleterious materials
8. Organic impurities
9. Micro fines content
10. Chloride and Sulphate Content
11. Petro graphical Analysis if Manufacturer does not possess.
12. Tests for Silt and clay

14.0. List of few labs for conducting test on CS-Sand are furnished below :

1. National Test House, Government of India, Taramani, Chennai.
2. ICOMAT- The IIT incubated lab, Perungudi, Chennai
3. Soil Mechanics and Research Lab, PWD, Taramani, Chennai.
4. Tamilaga Arasu Building Research Station, Taramani, Chennai.
5. MSME Laboratories of Tamil Nadu
6. Labs of various Engineering Colleges all over Tamilnadu.

Plastering

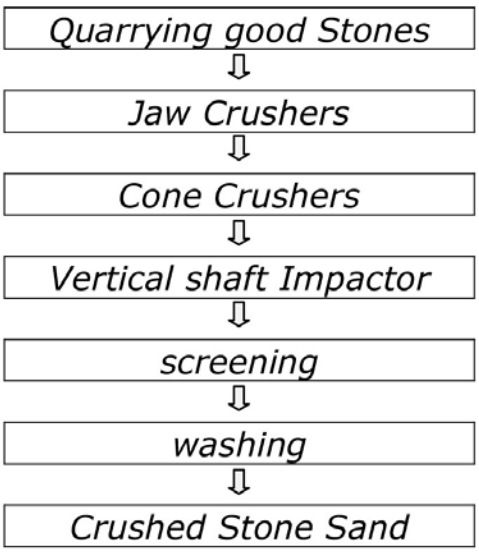
15.0. The specialized CS-Sand of particular gradation (as called Puuchchu Manal) should alone be used for plastering with addition of super plasticiser at the rate of 100ml per bag of cement for better bonding and achieving the required strength of plaster.

Caution

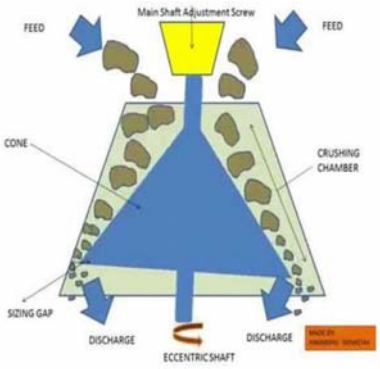
16.0. By-products during crushing of rocks are not Crushed Stone Sand. A Crusher Dust (or Quarry Dust) produced from fine screening of quarry crushing cannot be called Crushed Stone Sand.

The fine particles obtained, as by-products during crushing of rocks to produce coarse aggregates (by jaw crusher and/or cone crusher) are known as Quarry Rock Fines / Quarry Dust / Crusher Dust. These by-products are not suitable for concrete or mortar as they contain higher percentage of dusty, flaky particles of un-controlled sizes with high water absorbent property. If the crusher dust is flaky and angular in shape, the workability will be very difficult. There is no plasticity in the concrete and mortar which makes it even difficult for the mason to work, whereas if it is cubical in shape with grounded edge, will give superior gradation and good plasticity to concrete.

17.0. Crushed Stone Sand (CS-Sand) manufacturing process



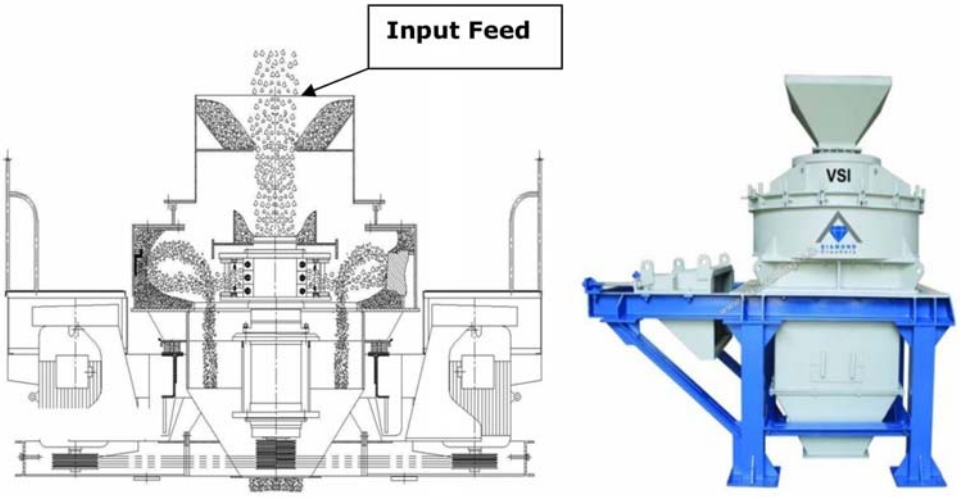
Jack Crusher



Cone Crusher

18.0. Vertical Shaft Impact (VSI) Crusher

This involves an important stage of using Tertiary crusher called Vertical Shaft Impact (VSI) Crusher which carries out a combined process of reducing coarser particles into finer particles and shaping the fine particles by removing the flaky and weak edges.



Vertical Shaft Impact (VSI) Crusher

19.0. Conclusion

Adhering to the above mentioned technical aspects and based on various studies conducted by Industry experts and also examination made by TNPWD, Use of Good quality Crushed stone Sand with distinctive properties manufactured following the above mentioned processes can be permitted in PWD for construction works as alternate to River Sand.

Further it is informed that, Good Quality Crushed Stone Sand provides greater durability and required strength to concrete by overcoming deficiencies like segregation, honey combing, voids and capillary action.

Hence, through this circular memorandum, it is instructed that all the officials of PWD are requested to use CS-Sand in construction activities as alternate to River Sand without any reluctance by adhering to all the above instructions.

The rates for Crushed Stone Sand and River Sand is provided vide page 19 of PWD Schedule of Rates for the year 2017-2018.

SEIVE ANALYSIS FOR M SAND

IS sieve	Percentage passing for			
	Grading zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150 micron	0-10	0.10	0.10	0-15

1 For crushed stone stands, the permissible limit on 150 µm IS sieve in increased to 20 percent. This does not affect the 5 percent allowance permitted in 6.3 applying to other sieve sizes.

2 Fine aggregate complying with the requirements of any grading zone in this table is suitable for concrete but the quality of concrete produced will depend upon a number of factors including proportions.

3 As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to IV, the ratio of fine aggregate to coarse aggregate should be progressively reduced. The most suitable fine to coarse ratio to be used for any particular mix will, however, depends upon the actual grading, particle shape and surface texture of both fine and coarse aggregates.

4 It is recommended that fine aggregate conforming to grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

5 Sand falling in Grade I is coarse and that falling in Zone IV is fine.

6 Sand falling in Grade IV shall not be used in reinforced concrete.

7 Ideally, Sand conforming to Zone II or Zone III should be used for concrete wherever possible.

8 Zone I sand tends to give harsh concrete that is sensitive to moisture changes and is prone to segregation.

9 Zone IV sand tends to give concrete of too much cohesion and the resultant mix is sticky and difficult to compact.

IS sieve designation	Percentage passing by Weight	
	For **Masonry Works** (IS:2116-1980)	For **Plastering Works** (IS:1542-1977)
10 mm	-	100
4.75 MM	100	95-100
2.36MM	90-100	95-100
1.18 MM	70-100	90-100
600 micron	40-100	80-100
300 micron	5-70	20-65
150 micron	0-15	0 - 50

7.1 SIEVE ANALYSIS OF CRUSHED STONE SAND

To determine the Sieve analysis, we need standard sieves, mechanical sieve shaker (optional), dry oven and digital weight scale.

Sample preparation

Take a sample of fine aggregate [near about 2 kg] in pan and placed it in dry oven at a temperature of 100 – 110 C. After drying take the 1000gm sample and note down it.

Test procedure

Take the sieves and arrange them in descending order with the largest size sieve on top.

If mechanical shaker is using then put the ordered sieves in position and pour the sample in the top sieve and then close it with sieve plate. Then switch on the machine and shaking of sieves should be done at least 5 minutes.

If shaking is done by the hands then pour the sample in the top sieve and close it then hold the top two sieves and shake it inwards and outwards, vertically and horizontally.

After some time shake the 3rd and 4th sieves and finally last sieves.

After sieving, record the sample weights retained on each sieve. Then find the cumulative weight retained.

Finally determine the cumulative passing percentage retained on each sieves.

EXAMPLE FOR GRADATION

IS Sieve Size	Weight Retained (gms)	% Weight Retained	Cumulative % Retained	Cumulative % Passing
(1)	(2)	(3)	(4)	(5)
10.00 mm	0	0	0	100
4.75 mm	030	03	03	97
2.36 mm	120	12	15	85
1.18 mm	150	15	30	70
600 µm	200	20	50	50
300 µm	320	32	82	18
150 µm	150	15	97	03
Pan	30		$\sum(4) = 277$	

RESULT IN ZONE

Now we can finalise our sand zone as per passing percentage in each sieve.

Fig Set of sieves

Fig Fine aggregates

Fig Set of sieves

Shaking of sieves

Sieving

Weighing

7.2 MATERIALS FINERS THAN 75 MICRON (IS:2386-PART 1-1963)

OBJECTIVE

For determination of the quantity of material finer than 75 micron IS sieve in aggregates by washing.

Wet sieving is carried out for separating fine grains from coarse grains by washing the sample on a 75 micron sieve mesh.

REFERENCE STANDARDS

IS : 2386 (Part I) – 1963 – Method of test for aggregates for concrete (Part I) Particle size and shape.

EQUIPMENT & APPARATUS

- Balance (0-10 kg)
- Sieves (1.18 mm,75 micron)
- Oven (3000c)
- Container

PROCEDURE

1. The sample (500 gm) is dried to constant mass in the oven at a temperature of 1100±50C.
2. After drying the test sample is placed in a container with sufficient water to cover the test sample, and is agitated vigorously to separate all the fine particles from the coarse particles
3. Then the entire test sample with water is poured over the nested sieves arranged with coarser sieve on the top and 75micron sieve at the bottom, and is washed under running water until wash water is clear.
4. All the material retained on the nested sieve is returned to the washed sample and is dried to constant weight at a temperature of not exceeding 1100C.

CALCULATION

The amount of material passing 75 micron IS sieve is calculated as follows

$$A = \frac{B - C}{B} \times 100$$

A = Percentage of material finer than 75 micron

B = Original dry weight

C = Dry weight after washing

REPORT

Materials finer than 75 micron is reported in percentage and rounded of to the nearest 0.5%.

Though IS 383:2016 accepts 15% as upper limit for presence of Micro fines, (<75 micron) according to Industry experts it is advisable to limit this upper value to 7%.

washing 75 mic sieves

washing 75 mic sieves
(2.36 sieve is kept over 75 micron sieve inorder to avoid tearing of minute nets in 75 micron sieve by coarser particles)

PUBLIC WORKS DEPARTMENT

BUILDINGS

**OFFICE OF THE ENGINEER-IN-CHIEF (BUILDINGS),
CHIEF ENGINEER (BUILDINGS) CHENNAI REGION AND
CHIEF ENGINEER (GENERAL), PWD.,
CHEPAUK, CHENNAI – 5**

Technical Circular No. AEE / T10 / 57017 , dated 12.09.2017

Sub : Building –Crushed Stone Sand (CS-Sand) manufactured by Firm.- Product approval by the PWD Assessment Committee -– Circular Instructions issued - Regarding

Ref :
1. G.O. Ms. No. 106, Department of Housing, dated 06.03.1975
2. Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD., Circular No. AEE / T10 / 57017 / dated 12.07.2017

****

1.0. In this office Circular 2nd cited orders were already issued to use the M Sand (technically called as Crushed Stone Sand) as alternate to River sand.

2.0. To ensure the quality of the M.Sand, all the firms manufacturing M Sand are hereby instructed to place their product in the PWD Assessment Committee for approval. The following are the details of the PWD Assessment Committee.

3.0. The Government in G.O. Ms. No. 106, Department of Housing, dated 06.03.1975 constituted Assessment Committee to evaluate the innovations in use of materials and construction techniques with representatives from various institutions. At now this committee meeting is convened twice in a year for approval of the new building products and electrical products to be used in PWD.

4.0. At present the Assessment committee functions with Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD.,, as Chairman and the Superintending Engineer, PWD Planning and Design circle Chennai as Member Secretary.

5.0. The members of this committee are drawn from Anna University, Indian Institute of Technology, Bureau of Indian Standards, Structural Engineering Research Centre, Tamil Nadu housing Board, Tamil Nadu Slum Clearance Board, Tamil Nadu Police Housing Corporation, Tamil Nadu Electricity Board, Directorate of Technical Education, Military Engineering Service, Institution of Engineers and Builders Association.

6.0. The Assessment committee examines the product details based on the Bureau of Indian standards license , the Test Reports from the Government laboratories such as National test house or MSME laboratories and Government Academic Institution such as IIT, Anna University etc and issues product approval certificates with a validity of three years. After three years firms should apply for renewal of approval with necessary details.

7.0. Now it is decided that the M Sand products manufactured by the firms also have to apply for the approval of the PWD Assessment Committee like other building materials to qualify for use in PWD Government projects.

8.0. In this connection the form of application/ checklist for approval to be submitted to the assessment committee is enclosed.

9.0. The application should be submitted along with the details of Registrations/ licences, the facilities available including the machineries etc along with the Test Reports from the State / Central Government laboratories such as National test house or MSME laboratories, or PWD SM&R Laboratory or Government Academic Institution such as IIT, Anna University, Government Engineering colleges. The test reports should show compliance of the specifications of M Sand as already issued in the circular 2nd cited.

10.0. After the application is received by the Chairman Assessment Committee, the product details shall be placed in the PWD Assessment Committee and approval Certificate shall be issued only upon approval by the committee

11.0. If required any nominated PWD Engineer shall inspect the manufacturing unit to verify the details furnished in the application for approval. After approval, if any deviation in manufacturing process/ quality of the products are noticed the approval shall be cancelled by the Chairman of the Assessment Committee at any time.

Hence, through this circular memorandum the firms which are manufacturing M Sand are requested to apply for approval of their product in the PWD Assessment Committee to qualify for the use of their Product in the Government works.

PUBLIC WORKS DEPARTMENT

BUILDINGS

**OFFICE OF THE ENGINEER-IN-CHIEF (BUILDINGS),
CHIEF ENGINEER (BUILDINGS) CHENNAI REGION AND
CHIEF ENGINEER (GENERAL), PWD.,
CHEPAUK, CHENNAI – 5**

Technical Circular No. AEE / T10 / 57017 , dated 24.11.2017

Sub : Building –Crushed Stone Sand (CS-Sand) –Seive Field Tests – Circular Instructions issued - Regarding

Ref : 1. Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD., Circular No. AEE / T10 / 57017 / dated 24-09-2017
2. Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD., Circular No. AEE / T10 / 57017 / dated 12.07.2017
3. Engineer-in-Chief (Buildings) & Chief Engineer (Buildings) Chennai Region and Chief Engineer (General), PWD., Circular No. AEE / T10 / 57017 / 2012, dated 30.08.2012

1.0. In this office Circular 2nd cited already issued to use the M Sand (technically called as Crushed Stone Sand) as alternate to River sand,it was insisted that CS-Sand should adhere to the highest standards and must undergo the required quality tests.

2.0. The M-Sand used in our departmental work should be of approved quality.

The M-Sand used for concrete works should satisfy the requirements stipulated in IS:383-2016.The M-Sand used for Masonry works should satisfy the requirements stipulated in IS: 211-1980.The M-Sand used for plastering works should satisfy the requirements stipulated in IS: 1542-1992 (ref Annexure –I)

2.0 In this circular it is insisted to carry out Sieve Analysis on each and every lot of M-Sand brought to the construction site before using it in any construction Works.

Particles less than 75 micron (Micro fines)

5.0. This test is done by “Wet Sieving” CS-Sand sample through 75 micron sieve through which the presence of Micro fines can be measured. Though IS 383:2016 accepts 15% as upper limit for presence of Micro fines, according to Industry experts it is advisable to limit this upper value to 7%.

Sieve for Grain size Analysis of CS Sand

Annexure I

Table 1 Gradation of CS-Sand to be used for concrete works
(IS 383-2016)

IS SIEVE DESIGNATION	PERCENTAGE PASSING FOR			
	Grading Zone 1	Grading Zone II	Grading Zone III	Grading Zone IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600micron	15-34	35-59	60-79	80-100
300micron	5-20	8-30	12-40	15-50
150micron	0-10	0-10	0-10	0-15

Table 2 Grading of CS-Sand for use in Masonry Mortars (IS 2116-1980)

IS Sieve Designation	Percentage Passing by Mass
4.75 mm	100
2.36 mm	90 to 100
1.18 mm	70 to 100
600 micron	40 to 100
300 micron	5 to 70
150 micron	0 to 15

Table 3 Gradation of M-Sand to be used for Internal Wall or External Wall or Ceiling Plaster(IS 15412-1992)

IS Sieve Designation (See IS 460:1985)	Percentage Passing
10mm	100
4.75mm	95-100
2.36 mm	95-100
1.18mm	90-100
600 micron	80-100
300 micron	20-65
150 micron	0-15

CHAPTER – VIII

QUALITY CONTROL ASPECTS

Quality Control Aspects consisting of Concrete – Cube Test, Acceptance Criteria as per IS 456-2000, Workability Of Concrete, Core Test for Concrete Structures, Non Destructive Tests (NDT) etc., are described as followes.

(i)CONCRETE – CUBE TEST

Concrete work. Systematic testing of the raw materials, the fresh concrete and the hardened concrete is an inseparable part of any quality control programme for concrete which helps to achieve higher efficiency of the materials used and greater assurance of the performance of the concrete in regard to both strength and durability. The test methods used should be simple, direct and convenient to apply.

(ii) ACCEPTANCE CRITERIA IN IS 456-2000

The prevailing clauses on acceptance criteria on IS 456-2000 to ensure the quality of concrete stipulate conditions to be satisfied in order to comply with the strength requirement

(iii) WORK ABILITY OF CONCRETE

The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available.

(iv) CORE TEST FOR CONCRETE STRUCTURES

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength test of concrete maybe carried out by core test.

(v)NON DESTRUCTIVE TESTS (NDT)

Non destructive test provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplements the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength.

8.1 CONCRETE – CUBE TEST :

PROCEDURE FOR CASTING OF CUBES

Size of test specimen :150mm x 150mm x 150mm CUBE

1. Clean the standard cube moulds 6 Nos. thoroughly and tight all nuts-bolts properly.
2. Apply oil to all contract surface of mould.
3. Size of mould is normally 150 mm x 150 mm x 150 mm.
4. Take the random sample from the mixing spot while concreting.
5. Fill the concrete in cubes in 3 layers.
6. Compact each layer with 35 Nos. of stroke by tamping rod.

7. Finish the top surface by trowel after completion of last layer.
8. Cover the mould by damp hesian cloth immediately to prevent loss of water.
9. Each specimen should be taken from various locations of proposed concreting.
10. After 24 hours remove specimen out of mould.
11. While removing, take care to avoid breaking of edges.
12. Put coding on cubes by paints or marker, coding should be self explanatory showing site name, concrete location, building number and date of casting.
13. Submerge the specimen in clean fresh water till the time of testing.
14. Test 3 specimens for 7 days and 3 specimens for 28 days curing.
15. Average strength of 3 cubes represents the strengths of concrete of particular portion of the structure.

Strength of concrete for various periods

(Table 5.1 - p298 - Properties of Concrete by Adam Neville)

Period	Strength
7 days	2/3 of 28day strength
28 days	1.0
2 months	1.1
3 months	1.16
6 months	1.2
12 months	1.24

8.2 ACCEPTANCE CRITERIA IN IS 456-2000

(Code for Plain and Reinforced Cement Concrete)

Though about two decades has completely passed since the release of IS 456-2000 (Code of Practice for Plain and Reinforced concrete) in July 2000 by the Bureau of Indian standards (BIS),Civil Engineers find it difficult to understand the clauses on acceptance criteria.

The prevailing clauses on acceptance criteria on IS 456-2000 to ensure the quality of concrete stipulate conditions to be satisfied in order to comply with the strength requirement and are explained below

Extracts from IS 456-2000

I. Sampling And Strength Of Designed Concrete Mix

Sampling frequency of Concrete(Clause 15.2.2-IS 456)

QTY OF WORK M3	NO. OF SAMPLES
1-5	1
6-15	2
16-30	3
31-50	4
51 & ABOVE	4+1 FOR EACH 50 m3 OR PART THERE OF

II. Characteristics compressive strength - compliance requirements

Condition 1 (Preliminary Condition)

TEST RESULTS OF SAMPLE (Clause 15.4)

The test results of the samples shall be the average of the strength of **THREE** specimens.

The individual variation should not be more than **± 15 % of the average.**

Condition 2 (Main Condition)

Acceptance Criteria

COMPRESSIVE STRENGTH: (Clause 16.1)

The concrete shall be deemed to comply with the strength requirement when both the following conditions are met, as per IS: 456-2000:

(a) The mean strength determined from any group of **4 non-overlapping consecutive test results** complied with the appropriate limits in columns 2 of the following table.

(b) Any individual test results complied with the appropriate limits in column 3 of the following table.

Table 11 (IS 456-2000)

Characteristics compressive strength compliance requirements

Specified grade	**Mean of the group of 4 non - overlaping consecutive test results in N/mm^2**	**Individual test results in N/mm^2**
M15	$\geq$ fck + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm^2) Or fck + 3 N/mm^2 whichever is greater	$\geq$ fck - 3 N/mm^2
M20 or above	$\geq$ fck + 0.825 x established standard deviation (rounded off to nearest 0.5N/mm^2) Or *fck + 3 N/mm^2 whichever is greater	$\geq$ *fck - 3 N/mm^2

In the absence of established value of standard deviation the following value may be assumed in the first instance and there after established values based on the requisite number of test results.

Grade of concrete	Assumed standard devotion (Table 8)
M10 and M15	3.5N/mm^2
M20 and M25	4.0N/mm^2

fck = Characteristic compressive strength of 150mm cube at 28 days in N/mm^2.

For M15 & M20 grades, fck is 15N/mm^2 and 20N/mm^2 respectively.

Note: * Originally for M 20 or above, * fck+4 N/mm^2 & $\geq$ *fck - 4 N/mm^2 were mentioned in the code; but later corrected as , *fck+3 N/mm^2 & $\geq$ *fck - 3N/mm^2 in the amendment

Illustrative Example

Case 1 (When Quantity of Concrete is large i.e., more than 30 m3)

Say **(M 20)** concrete work of **quantity 40 m^3** has been done for a large work. Hence as recommended by the clause 15.2.2 of the code four **samples** (i.e., 12 cubes) has been casted.

After conducting cube tests (M20),three values Obtained are say

x1, x2, x3

Say x1 : **18** N/mm2

X2 : **22** N/mm2

X3 : **23** N/mm2

p1= Average: (18+22+23)/ 3 = **21** N/mm2

(± 15% of 21) => (1.15 x 21 = **24.15**)

& (0 .85x21 = **17.85**)

Condition 1 (Preliminary Condition)

TEST RESULTS OF SAMPLE (Clause 15.4)

The test results of the samples shall be the average of the strength of **THREE** specimens. The individual variation should not be more than **± 15 % of the average**.

Here, individual variation is within 15%

Hence Individual Results are valid.

Condition 2 (Main Condition)

***Acceptance Criteria*(Clause 16.1)**

Find out p1, p2, p3, p4 Where, p1 = Average i.e.,(x1+x2+x3) / 3

p2 = Average i.e.,(y1+y2+y3) / 3 .....

p1=21 p2=27 p3 =29 p4=19

(p1+ p2 + p3 +p4) /4 =[(21+27+29+19)/4] = **24.0 N/mm2** - **(A)**

Characteristics compressive strength compliance requirements (Table 11)

(i) *fck + 3 = 20 + 3 =**23** N/mm2*

(or)

(ii) *fck+ (0.825 x 4 =20 + .825 x 4.0)=23.3 say **23.50** N/mm2)*

whichever is greater.

Here it is 23.50 N/mm2 - (B)

(A) should be greater than *(B)as per main condition,*

In this case (A) > (B). (i.e., 24.0 > 23.50)

Hence it can be easily concluded that the above cubes comply with the strength requirement and hence O.K.

8.3 WORKABILITY OF CONCRETE

The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available.

DETERMINATION OF CONSISTENCY OF CONCRETE (BY SLUMP TEST)

(Method for measuring workability)

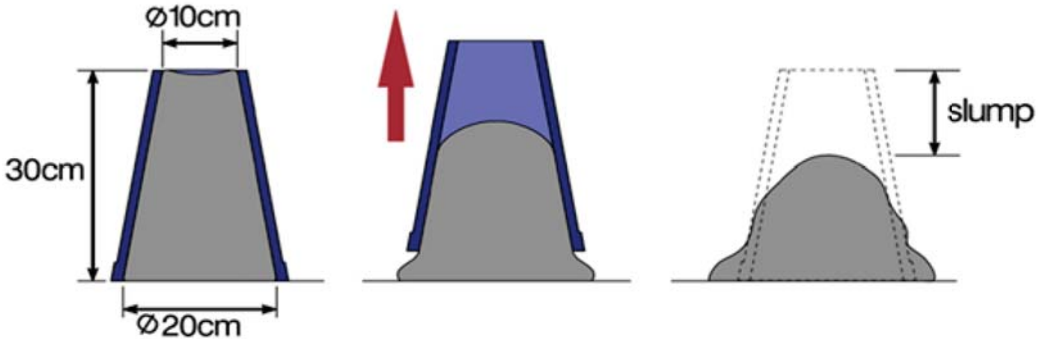
Apparatus

Mould for Test specimen (Frustum of cone 20 cm in diameter at bottom, 10 cm at the top and 30 cm in height,) tamping rod 16 mm dia and 60 mm long.

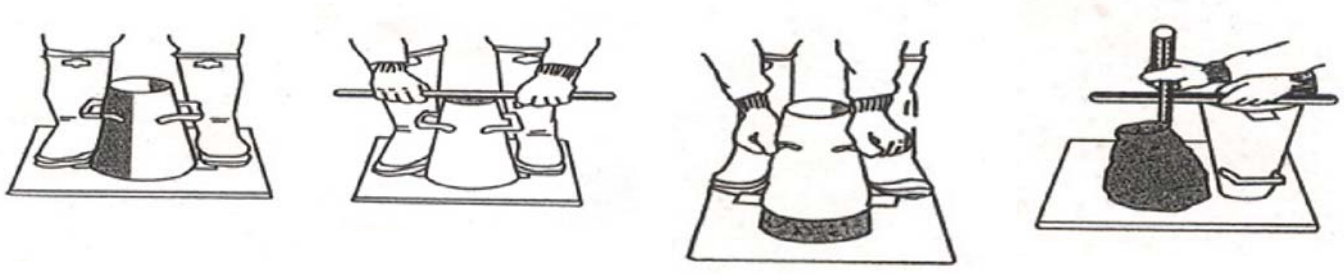
Test Procedure

1) The mould is filled with concrete in 7.5 cm layers

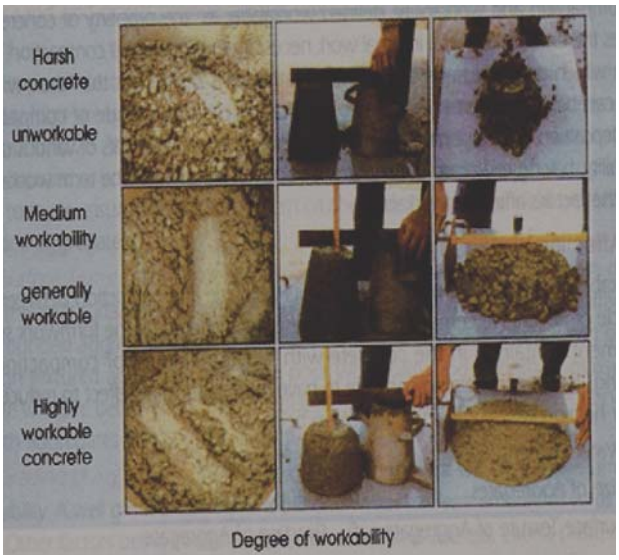
2) Each layer is compacted with 25 strokes of 16 mm diameter tamping rod.



3) The strokes should be applied uniformly over the entire area and with such a force that the rod just penetrates the full depth of the layer being compacted.



4) The mould is then removed just after filling, care being taken not to disturb concrete and the concrete is allowed to settle and the vertical settlement is known as "Slump"



Workability and Slump

Workability	Slump
Very Stiff	No Slump
Stiff – to be vibrated	0 to 25 mm
Stiff Plastic – Mass Concrete	25 to 50 mm
Plastic – RCC work	75 to 100 mm
Flowing- cast-in-situ pile work	150 to 175 mm

Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below: (Ref Clause 7.1 of IS 456-2000)

Placing Conditions (1)	Degree of Workability (2)	Slump (mm) (3)
Blinding Concrete; Shallow sections; Pavements using pavers	Very low	See 7.1.1
Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
Heavily reinforced sections in slabs, beams, walls, columns; Slip form work; Pumped concrete	Medium	50-100 75-100
Trench fill; In-situ pilling Tremie concrete	High Very High	100-150 See 7.1.2 (IS 456-2000)

NOTE - For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections

8.4 Core Test for Concrete Structures

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength test of concrete maybe carried out by core test.

Core drilling method is the most direct way of measuring the actual strength of concrete in the structure. It mostly involves proper selection of location and number of samples to be obtained. Core should be taken so as to avoid the reinforcement. If avoidance of secondary reinforcement or surface reinforcement is inescapable, strength of Core can be taken as 10% less than measured strength. Cylindrical specimen of 100mm or 150mm diameter are common; other sizes may also be permitted but the least lateral dimension should not be less than 3 times the maximum size of the aggregates used. The core specimen to be tested should preferably have height of specimen as twice the diameter. If there are difficulties of obtaining samples of such size, the length to diameter ratio is permitted to be lower, but in no case lower than 0.95. The samples are to be stored in water for two days prior to testing and are to be tested in moist condition. The ends of specimens are trimmed and flatten and capped with molten sulphur or high alumina cement or some other permissible capping material to obtain a true flat surface. The specimen is then tested in compression.

Although drilling of cores and compressive strength test are quite simple (and are covered in IS:1199 and IS:516), but the procedures and influencing factors are to be carefully understood as they affect the measured value and therefore the assessment of the quality of in-place concrete. The provision of IS 456: 2000 vide clause 17.4.3 in this regard is given below:

“Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of concrete specified for the corresponding age and no individual core has strength less than 75 percent.”

Core Cutting

Core

- Core tests are carried out to ascertain segregation, honey-combing, thickness of concreting and the compressive strength of concrete in any concrete structure.
- Shape of Specimen – Cylindrical
- Specimen to be tested on the 28th day for comparison with casted cube.
- Minimum no. of cores to be tested - 3
- Specimen to be submerged in water for 48 hours
- The specimen is tested for Compressive strength after surface - levelling and capping

- Shape of Specimen – Cylindrical
- Dia > 3 x (max. nominal size of C.A.)
- Length = 2 x dia

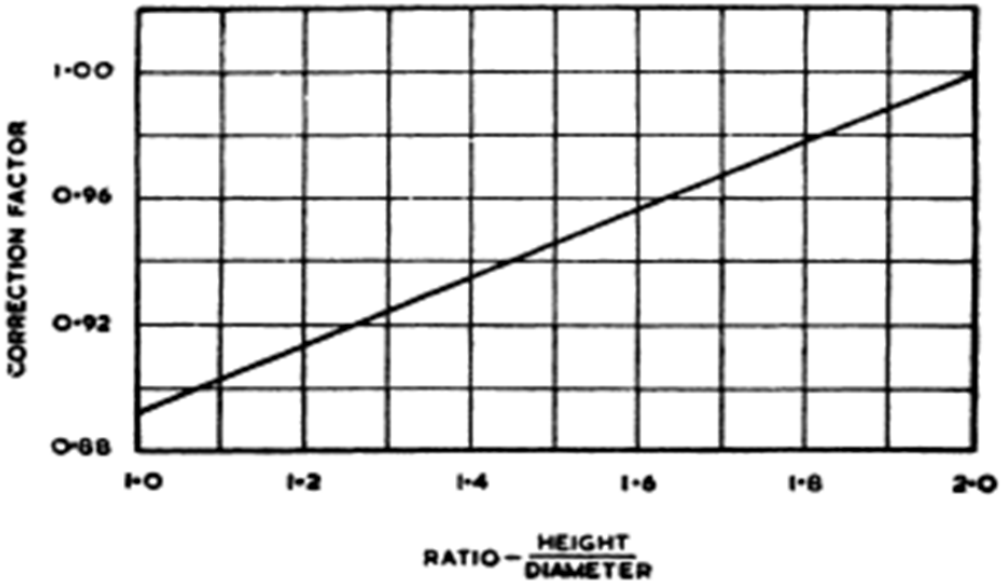


FIG. 1 CORRECTION FACTOR FOR HEIGHT-DIAMETER RATIO OF A CORE

As per IS 516 -1959 (Cl. 5.6.1)

Equivalent Cube Strength of Core =

1.25 x Cylinder Strength

Acceptance of Core Test (IS 456-2000-Cl. 17.4)

Condition 1

- Equivalent Cube Strength of Individual Core >

  75% of Cube Strength of Grade of Concrete

Condition 2

- Average Equivalent Cube Strength of Core >

  85% of Cube Strength of Grade of Concrete

Say Concrete Grade: 20N/mm^2

eg: If, Cylinder Strengths (P) in N/mm^2 = 1)13 2) 14 3) 15

Equivalent Cube Strength of Cores = 1) 16.25 2)17.50 3) 18.75
(= 1.25 x P)

Condition 1

Equivalent Cube Strength of Individual Core (i.e.,) 1) 16.25 2)17.50 3) 18.75

>75% of Cube Strength of Grade of Concrete (0.75x20=15 N/mm2)

Condition 2

Average Equivalent Cube Strength of Core = (16.25+17.5+18.75)/3 =
17.50 N/mm^2

85% of Cube Strength of Grade of Concrete =.85 x 20 =17

Average Equivalent Cube Strength of Core (17.50 N/mm^2)

> 85% of Cube Strength of Grade ofConcrete(17 N/mm2)

Core Test O.K

8.5 NON DESTRUCTIVE TESTS (NDT)

Non destructive test are used to obtain estimation of the properties of concrete in the structure. The methods adopted include Ultrasonic Pulse Velocity (UPV) Tests & Rebound Hammer Tests .

Non destructive test provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplements the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

Rebound Hammer Test

UPV Test

8. 5.1 CONCRETE REBOUND HAMMER

IS : 13311 (PART 2) : 1992

APPRATUS

1. REBOUND HAMMER

CHECKING OF APPARATUS

The testing anvil should be of steel having Brinell hardness of about 5000 N/sq.mm.

CALIBRATION OF APPARATUS

1. Establish a correlation between compressive strength of concrete and it rebound number on concrete cubes.
2. The Concrete cube specimens are held in a CTM under a fixed load, measurements of rebound number taken and then compressive strength determined as per IS : 516:1959.

3. If the specimens are wet cured, keep the cubes in atmosphere for 24 hrs before testing. Establish a correlation between the strength of wet tested cubes and strength of dry tested cubes on which rebound readings are taken.

4. Only vertical faces of the cube as cast should be tested.

5. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers.

6. The points of impact on the specimen must not be nearer an edge than 20mm and should be not less than 20 mm from each other.

7. The same points must not be impacted more than once.

Cube No.	Length mm	Width mm	Crushing Load N	Compressive strength MPa	Rebound reading on face 1 (9 readings)	Rebound reading on face 2 (9 readings)	Average rebound index
1.	150	150					
2.	150	150					
3.	150	150					

PROCEDURE

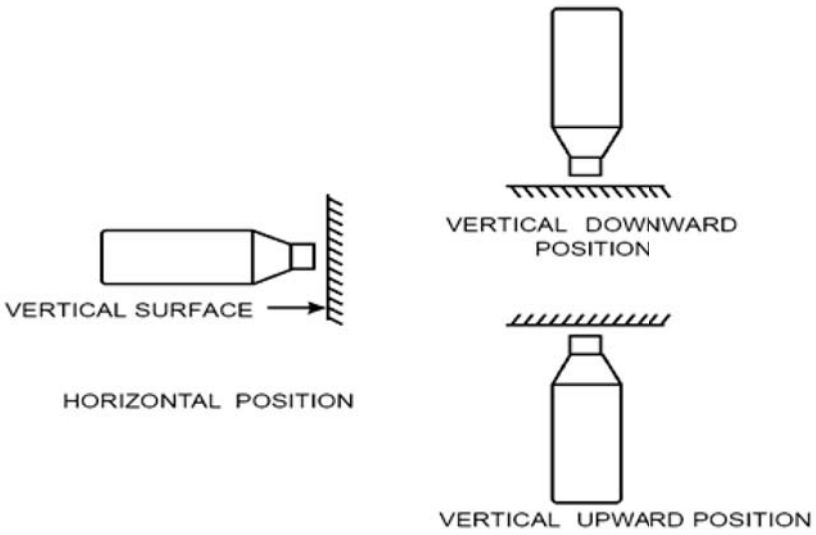
1. Select smooth, clean and dry surface for the test. If the surface is rough make it smooth and clean because rough surfaces resulting from incomplete compaction, loss of grout, spalled or tooled surfaces do not give reliable results and should be avoided.

2. The point of impact should be at least 20 mm away from any edge or shape discontinuity.

3. Hold the rebound hammer at right angles to the surface of the concrete member and take the measurement. Thus the test can be conducted on horizontally or vertical surfaces or vertical upwards or downwards on horizontal surfaces.

4. If the situation demands the rebound hammer can be held at intermediate angles also, but in each case the rebound number will be different for the same concrete.

5. Rebound hammer test is conducted around all the points of observation on all accessible faces of the structural element. Around each point of observation six readings of rebound indices are taken and average of these reading after deleting outliners as per IS:8900:1978 becomes the rebound index for the point of observation.



INTERPRETATION OR RESULTS

1. The rebound hammer provided a convenient and rapid indication of the compressive strength of concrete by means of establishing a suitable correlation between the rebound index and the compressive strength concrete.

2. In general, the rebound number increases as the strength increases but it is also affected by a number of parameters as mentioned below.

Note : 1. The rebound indices are indicative of compressive strength of concrete to a limited depth from the surface. It cannot indicate the internal micro cracking, flaws or heterogeneity across the cross-section of the concrete, if any.

2. Since the method is not accurate the probable accuracy of prediction of concrete strength in a structure is +/-25%.

3. The rebound numbers are influenced by Types of cement, aggregate, surface condition and Moisture content of the concrete, curing and age of concrete, carbonation of concrete surface.

GUIDELINES FOR QUALITATIVE INTERPRETATION OF REBOUND HAMMER TESTS **

AVERAGE REBOND NUMBER	QUALITY OF CONCRETE
> 40	VERY GOOD HARD LAYER
30 to 40	GOOD LAYER
20 to 30	FAIR
< 20	POOR CONCRETE
0	DELAMINATED

NUMBER OF HAMMER READINGS REQURIED AS PER SPECIFICATIONS

Specification	Specification No.	Required readings
Indian Standard	IS : 13311 (Part 2) : 1992	6
British Standard	BS : 4408; Part 4 : 1971	9 valid readings ; NMT 25
CPWD	CPWD - 2002	12
ASTM	C805	10

IS THE REBOUND HAMMER TEST CAN BE CONSIDRED AS A STANDARD TEST FOR THE DETERMINATION OF STRENGTH OF THE CONCRETE ?

1. Schmidt hammer is not a standard test for acceptance test of concrete strength. It is only a test used for estimating the strength of concrete in structure and it can hardly be considered as a substitute for compressive strength test.

2. Though the method provides quick information on the quality of concrete, it has some limitations. One of the limitations is that it represents the hardness of the surface only and gives no idea bout the quality of concrete inside. Also the results of the hammer are affected by smoothless, carbonations and moisture content of the concrete surface, etc.

3. Further, it is difficult to justify a accurate theoretical relationship between the rebound number and strength of concrete tested. As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is +/-25 percent.

8. 5.2 NON-DESTRUCTIVE TESTING OF CONCRETE ULTRASONIC PULSE VELOCITY

IS : 13311 (PART- I) : 1992

Ultrasonic Pulse Velocity (UPV) testing of concrete is based on the pulse velocity method to provide information on the uniformity of concrete, cavities, cracks and defects. The pulse velocity in a material depends on its density and its elastic properties which in turn are related to the quality and the compressive strength of the concrete. It is therefore possible to obtain information about the properties of components by sonic investigations. Commonly used instrument is PUNDIT (Portable Ultrasonic Non-destructive Digital Indicating Tester).

The ultrasonic pulse velocity method could be used to establish, the homogeneity of the concrete.

The presence of cracks, voids and other imperfections changes in the structure of the concrete which may occur with time.

The quality of the concrete in relation to standards requirements.

The quality of one elements of concrete in relation to another and

The values of dynamic elastic modulus of the concrete.

STANDARDS SPECIFICATION FOR UPV TEST

- Indian Standard IS : 13311 (Part) 1992
- British Standard BS : 1881-203
- ASTM-C597

PRINCIPLE

Ultrasonic Pulse Velocity testing is basically a wave propagation test

The rest consists of transmitting electro acoustic pulses through the concrete medium from one side, receiving the signal from the other side and measuring he transit time.

The path length between the transmitting and receiving point is measured and the pulse velocity is calculated by dividing the path length by the transit time.

Pulse velocity is influenced by the properties of concrete which determine its elastic stiffness and mechanical strength.

Reduction in the pulse velocity is observed when concrete under the test has low compaction, voids or damaged materials.

The pulse velocity increase or decreases as the concrete matures or deteriorates or changes with time.

This method is considered to be a valuable and reliable method of examining the anterior of concrete in a NDT way.

The strength prediction part is unreliable due to number of factors influencing the calibration. In order to evaluate the strength of concrete a calibration chart should be established on laboratory tests.

APPARATUS : The apparatus for Ultrasonic Pulse velocity measurement shall consist of the following:

- Electrical pulse generator
- Transducer
- Amplifier and
- Electronic timing device

TRANSDUCER :

Any suitable type of transducer operating within the frequency range of 20 KHz to 150KHz may be used.

Piezoelectric and magneto-strictive types of transducers may be used and the magneto-strictive types of transducers are more suitable for the lower part of the frequency range.

ELECTRONIC TIMING DEVICE

It shall be capable of measuring the time interval elapsing between the onset of pulse generated at the transmitting transducer and the onset of its arrival at the receiving transducer.

PERFOMANCE OF THE ASSEMBLY OF APPARATUS

The apparatus should be capable of measuring transit times to an accuracy of +/-1 percent over a range of 20 microseconds to 10 milliseconds. For this, it is necessary to check the overall performance by making measurements on two standard reference specimen in which the pulse transit times are known accurately.

Two reference specimens (usually steel bars) should have pulse transit times of about 25 microseconds to 100 microseconds respectively, these times being specified by the supplies of the equipment to an accuracy of +/-0.2 micro second.

The shorter of the reference specimens is used to set the zero for the apparatus and the longer one is used to check the accuracy of the transit time measurement of the apparatus.

The measurement obtained should not differ from the known value for the reference specimen by more than +/-0.5%

PROCEDURE

Step 1 Smoothen the surface, divide and mark the surface in 30x30 cm and measure the path length (L)

Step 2 Apply the couplant, (Petroleum jelly) and hold the transducer in contact with one surface of the concrete member under test.

Step 3 Apply the couplant and hold the transducer in contact with the other surface of the concrete member.

Step 4 Measure the transit time (T) from the electronic timing device.

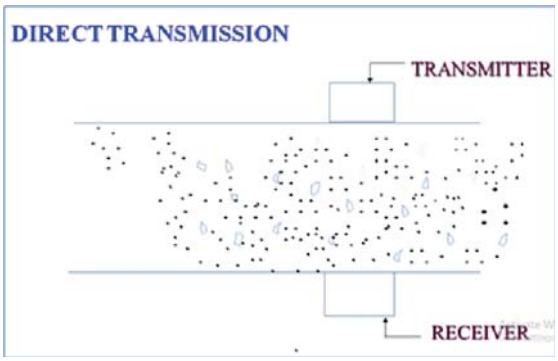
Step 5 The Pulse Velocity (V) is given V=L/T by

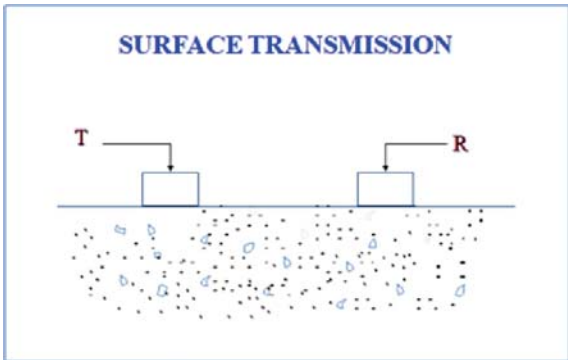
Sl. No	Pulse Velocity by Cross Probing (km/sec)	Concrete quality grading
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

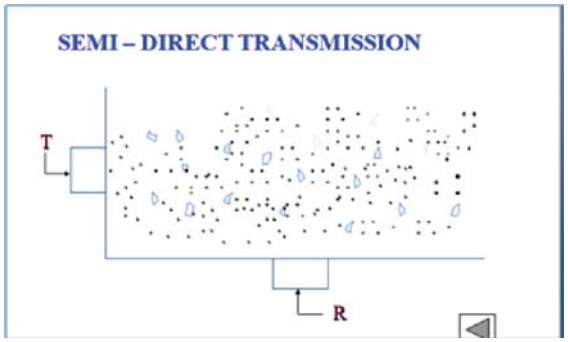
Note : In case of "doubtful" quality it may be necessary to carry out further tests.

Different type of methods are available for using the UPV tester.

1. Direct method (Cross Probing)
2. Semi direct method and
3. Indirect method (Surface Probing)







Surface Probing is not so efficient as cross probing, because the signal produced at the receiving transducer has an amplitude of one 2 to 3 percent of that produced by cross probing and the test results are greatly influenced by the different properties from that of concrete inside the structural member.

The indirect velocity is invariably lower than the direct velocity on the same concrete element. This difference may vary from 5 to 20 percent depending largely on the quality of the concrete under test.

A minimum path length of 150 mm is recommended for the direct transmission method involving one unmoulded surface and minimum of 400m for the surface probing method along an unmoulded surface.

Since the size of the aggregate influences the pulse velocity measurement, it is recommended that the minimum path length should be 100 mm for concrete in which the nominal maximum size of aggregate is 20 mm or less and 150 mm for concrete in which the nominal maximum size of aggregate in between 20 to 40 mm.

The natural frequency of transducers should preferably be within the range of 20 to 150 KHz. Generally high frequency transducers are preferably for short path lengths and low frequency transducers for long path lengths. Transducers with a frequency of 50 to 60 KHz are useful for most all-round applications.

In view of the inherent variability in the test results, sufficient number of readings are taken by dividing the entire structure in suitable grid markings at 30x30 cm or even smaller. Each junction point of the grid becomes a point of observation.

Surface probing in general gives lower pulse velocity than in case of cross probing and depending on number of parameters, the difference could be of the order of above 1 km/sec.

The test results are influenced by surface condition, moisture content of concrete, path length, shape and size of the concrete member, temperature of concrete and reinforcing bars.

Combined use of Rebound hammer and Ultrasonic pulse Velocity Method

In view of the relative limitations of either of the two methods for predicting the strength of concrete, both ultrasonic pulse velocity (UPV) and rebound hammer methods are sometimes used in materials, mix and environmental, parameters on the respective measurements. Relationship between UPV, rebound hammer and compressive strength of concrete are available based on laboratory test specimen. Better accuracy on the estimation of concrete strength is achieved by use of such combined methods.

However, this approach also has the limitation that the established correlations are valid only for materials and mix having same proportion as used in the trials. The intrinsic difference between the laborator test specimen and in-situ concrete (eg) surface texture, moisture content, presence of reinforcement, etc.) also affect the accuracy of test results.

Combination of UPV and rebound hammer methods can be used for the assessment of the quality and likely compressive strength of concrete is made from the rebound indices and this is taken to be indicative of the entire mass only when the overall quality of concrete judged by the UPV is 'good'.

When the quality assessed in 'medium', the estimation of compressive strength by rebound indices is extended to the entire mass only on the basis of other collateral measurement eg. Strength of controlled cube specimen, cement content of hardened concrete by chemical analysis or concrete core testing.

When the quality of concrete is 'poor', no assessment of the strength of concrete is made from rebound indices.

8. 5.3 DETERMINING THE LOCATION / DIAMETER OF REINFORCEMENT BARS AND COVER THICKNESS IN CONCRETE

The following methods are generally used for determining the location / diameter of reinforcement bars and cover thickness in buildings

(a) Profometer (b) Micro cover meter

PROFOMETER:

Profometer is a small versatile instrument for detecting location, size of reinforcement and concrete cover. This instrument is also known as rebar locator.

This is a portable and handy instrument which is normally used to locate the reinforcement on LCD display. This instrument is available with sufficient memory to store measured data. Integrated software is loaded in the equipment for carrying out and printing statistical values.

The equipment is quite handy and weighing less than two kgs. It works on normal batteries and thus does not require any electrical connection.

Object:

This test is used to assess the location and diameter of reinforcement bars and concrete cover. This equipment can be used effectively for evaluation of new as well as old structures. The method can be used both for quality control as well as quality assurance.

Principle:

The instrument is based upon measurement of change of an electromagnetic field caused by steel embedded in the concrete.

Methodology:

To ensure satisfactory working of profometer and to get accurate results, it should be calibrated before starting the operations and at the end of the test. For this purpose, test block provided with the instrument should be used. To check the calibration accuracy, the size and cover of the reinforcement of the test block is measured at different locations on test block and the recorded data should match with the standard values prescribed on the test block.

Path measuring device and spot probes are together used for path measurements and scanning of rebars. These are connected with profometer with cables and are moved

on the concrete surface for scanning the rebars and measuring the spacing. As soon as the bar is located, it is displayed on the screen. Once the bar is located, it is marked on the concrete surface.

Diameter probe is used for measuring the dia of bars. It is also connected with profometer by one cable. After finding out the location of rebar, the dia probe is placed on the bar parallel to bar axis. Four readings are displayed and mean value of these readings is taken as diameter of bar.

Depth probe of the profometer is used to measure the cover. It is also connected with profometer by cable and is placed exactly on the bar As soon as, the depth probe is above a rebar or nearest to it, it gives an audio signal through a short beep and visual display. Simultaneously, the measured concrete cover is stored in memory.

For carrying out this test, the proper assess is essential. For this purpose, proper staging, ladder or a suspended platforms may be provided. Before actual scanning, marking is done with chalk on the concrete surface by dividing it into panels of equal areas.

Advantages and Limitations:

This is a purely non-destructive test for evaluation of concrete structures particularly old structures. The methods is very fast and gives quite accurate results if the reinforcement is not heavily congested. The equipment is very light and even one person can perform the test without any assistance.

8. 5.4 Micro covermeter:

This is a portable and handy instrument weighing about 0.5 kg. This is normally provided with two types of search heads one for parallel bars having range approx. 360mm and other for mesh and close spaced bars having range of approx. 120mm. It can function over the temp. range of 0°C to 45°C. One of the micro cover meter commercially available in the market is shown in Fig.

The equipment is of 180mm x 100mm x 45mm size approximately. The equipment is available with volatile memory that helps in storing data while taking measurements.

Object:

The test is aimed mainly to detect the location and cover of reinforcement. The test may be used for analyzing the integrity of the structures as the cover thickness is an important aspect of construction. In the coastal areas, the test can be used for deciding the effectiveness of cover as well as rehabilitation measures required.

Principle:

The equipment consists of a highly permeable U-shape magnetic core on which two coils are mounted. When an alternating current is passed through one of these coils, the current induced in the other coil can be measured. The presence of steel affects the electromagnetic field. The induced current depends upon the mutual inductance of the coils and the nearness of the steel bars. A moving coil meter measures the current. For measurement of the cover, the probe is placed directly over the concrete member and moved slowly until reading is obtained on the dial. The probe should be kept parallel to the length of rebar. Depending upon the diameter of the bar, the dial readings gives directly the cover to the reinforcement.

Methodology:

The equipment should be calibrated before starting and at the end of the test to get accurate results. For this purpose, one spacer is provided with each equipment. For calibration, the cover should be measured at one location and then it is remeasured after placing the spacer between the concrete surface and probe. The difference between two readings should not vary more than +/- 5% of the thickness of the spacer.

For locating the reinforcement bar, the search head should be placed on the surface of concrete in such a way so that the length of the search head should be parallel to the reinforcement provided in the structure. The location of the main reinforcement should be decided based upon the geometry of the structure. The search head should be moved from one end to other end in a direction perpendicular to the main reinforcement. The sound of the buzzer /beep will be strongest when the bar will come just above or below the probe.

For measurement of cover, the search head is moved on the surface. While moving, the cover displayed on the screen reduces and sound of the buzzer/beep increases when probe comes near reinforcement bars. The minimum reading displayed will be the cover and the sound of the buzzer is strongest when the reinforcement bar is just below the search head.

Advantages and Limitations:

The method is very fast and large area can be covered within short time. The instrument work on batteries and does not require any electric supply. Since the equipment is very small and portable, the test can be conducted by single person

CHAPTER - IX

CRACKS IN BUILDINGS

(Causes and prevention)

9.1 Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, or foundation settlement or it could be induced internally due to thermal movements, moisture changes, chemical action, etc.

Cracks could be broadly classified as structural or non-structural. Structural cracks are those which are due to incorrect design, faulty construction or overloading and these may endanger the safety of a building.

Extensive cracking of an RCC beam is an instance of structural cracking. Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening.

In course of time, however, sometime non-structural cracks may, because of penetration of moisture through cracks or weathering action, result in corrosion of reinforcement and thus may render the structure unsafe.

Vertical cracks in a long compound wall due to shrinkage or thermal movement is an instance of non- structural cracking. Non-structural cracks, normally do not endanger the safety of a building, but may look unsightly, or may create an impression of faulty work or may give a feeling of instability.

9.2 REPAIR OF CRACKS IN BRICKWORK IN BUILDINGS

Cracks occur in walls due to differential movements caused by temperature, settlement of foundation, shrinkage, etc. From the nature of the cracks, we can infer the seat of movement. A line drawn normal to the cracked line will intersect the seat of settlement as shown in Fig.9.1

Any leakage of drains and consequent softening of soil or other types of settlement or movements can be the cause of these cracks.

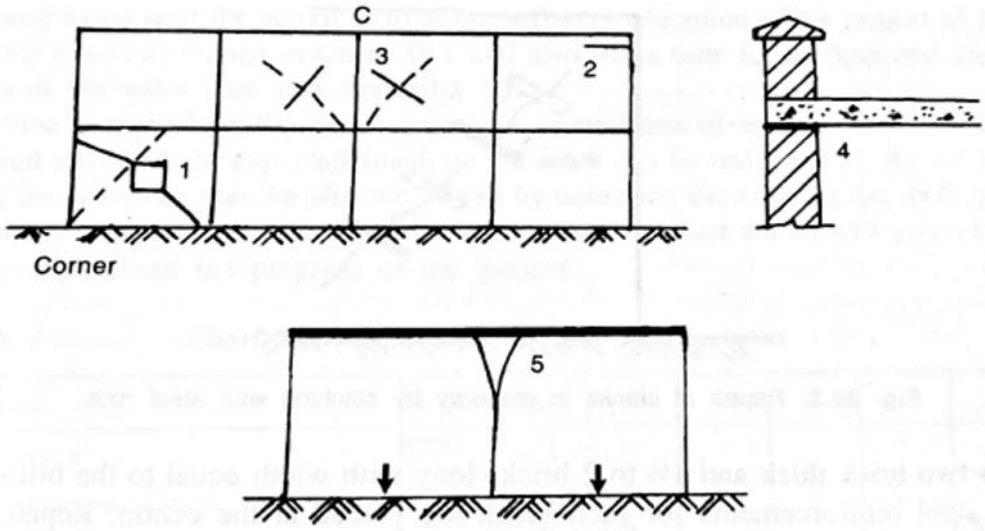


Fig 9.1 Cracks in Masonry due to various causes

1 =Crack due to settlement of corner
2= Crack under RC Slab due to lifting up of corners in two way slabs
3=Cracks due to settlement of column C
4 = Cracks below slab as a result of the movement due to temperature effect
5 =Crack with larger width at top due to heaving of centre as occurs in Black Cotton Soil

The first step before repair of cracks is to find the cause of the cracks and try to remedy the cause. For example, if the cause is due to foundation movement, it is worthwhile to proceed as follows.

a) If there is any leakage of drains, gulleys, manholes, it can soften the foundation soil and cause differential settlement. Such leakage should stopped.

b) In clayey soils, the foundation can be strengthened (for example, by plastering the brickwork below the ground level which might not have been plastered). In more serious cases, the foundation soil can be improved by lime injection or some other means. Otherwise, the foundation itself can be strengthened by underpinning.

The cracks in brick walls can be repaired by the following methods:-

1. If the cracks are less than 1.5 mm in width, they are generally filled up with putty (made at site or commercially available) and painted.
2. Cracks which are wider than 1.5 mm but are not very serious are repaired by raking them out to about 25 mm and refilling with 1 cement, 2 lime, 9 sand mortar or preferably with other patented crack-filling compounds available in the market. Separate types of elastic crack-filling compounds

– one suitable for small cracks in the form of paint and another suitable for large cracks (in the form of a semi-solid paste) – are available for filling the cracks. These are superior to Portland cement mixes.

GUNITE AND SHOTCRETE WORK FOR REPAIR OF CONCRETE

Gunite and Shotcrete

Gunite is one of the popular methods used to repair damaged concrete members. Gunite is the process of depositing mortar with low water-cement ratio at a high pressure through a nozzle. It was introduced in 1900. Recently the process has been improved so that only the concrete with small-sized coarse aggregate (instead of mortar) generally referred to as shotcrete can be deposited by this process. In both cases, the damaged part of the member (such as the underside of a roof slab) is cleaned before the operation and gunite or shotcrete is applied.

by using reinforced mortar or concrete stitching blocks. Thin mortar blocks can then be stuck on both sides of the brickwork or thick concrete blocks can be inserted in the brickwork at every 5th or 6th course as shown in Fig.9.2

Thin mortar blocks (1 ½ to 2 brick length, 100 mm wide and 25 mm thick) are made with 1:3 mortar with one 6 mm reinforced embedded at the centre. These blocks after curing are inserted in holes made at every 5th course of the brickwork (0.5 m spacing) on both sides. The masonry needs to be chased only to 25 to 30 mm into the brickwork for its insertion. Alternately, reinforcement rods are inserted instead of these blocks, but it should be made sure that they are covered with a thick coat of mortar and are not in contact with the bricks.

When repairing with thick concrete blocks, the wall has to be cut to its full depth and the RC blocks have to be inserted at regular intervals. The blocks are of 1:2:4 concrete made one or two brick thick and 1 ½ to 2 bricks long with width equal to the brickwork. Two 6 mm mild steel reinforcement for each block are placed at the centre. Repair consists in sticking the crack with these blocks at every 5th or 6th course.

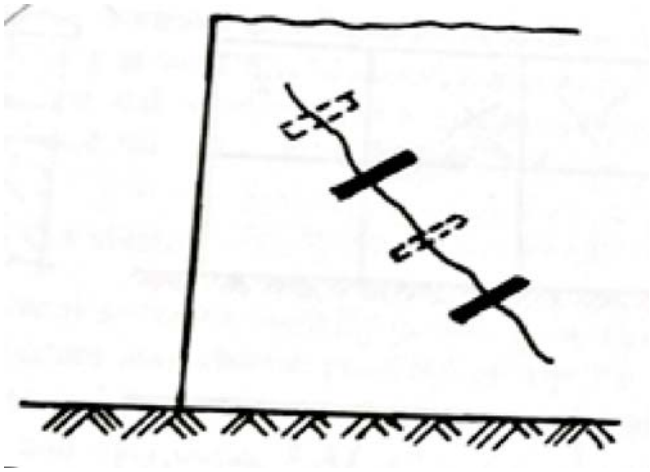


Fig. 9.2 Repair of cracks in masonry by stitching with steel rods.

REPAIRS OF RC WORKS DUE TO CORROSION OF STEEL

There are many types of repairs and the most common repair is the repair of spalling due to corrosion of steel which is discussed further.

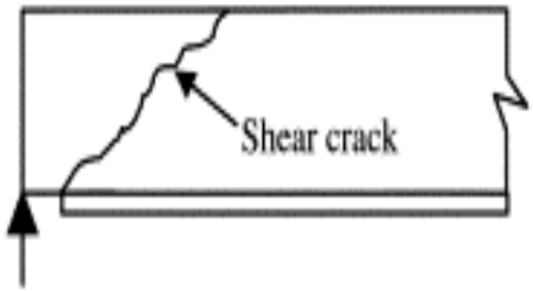
We come across a large number of cases where the steel reinforcements corrode due to various causes such as lack of cover, leakage of roof, etc. As steel rust occupies very much larger volume (more than 10 times) than steel, the surrounding concrete cracks and tends to get separated from steel and finally it falls down. This is particularly important in the ceiling plaster under leaking roofs. If we notice any disturbance in this plaster, it should be repaired as soon as possible. There are many cases in which the ceiling plaster has fallen down suddenly.

The repair for such cases is carried out as follows:-

1. Hammer test the area for loose areas and remove all loose particles of mortar, concrete, rust, etc. from the spalled surface and clean it with a wire brush.
2. Apply two coats of polymer modified active corrosion inhibitor to the remaining steel. (If additional steel is required, tie the new steel to the old steel by binding wires) Two coats of chromate paint can also be a substitute.
3. Apply one coat of polymer bonding agent (latex based) over the entire area of steel and concrete to be treated.
4. Apply polymer modified 1:3 cement mortar over the reinforcement and provide necessary cover. Addition of superplasticizer to reduce water and the incorporation of fibres will help to produce strong mortar. If the area is large, guniting with additive for quick setting can be used for better efficiency of the work.
5. Cure the concrete.
6. Apply a coat of waterproofing slurry coating for protection against environment, if necessary.

CRACKS ON BEAMS

SHEAR CRACKS:



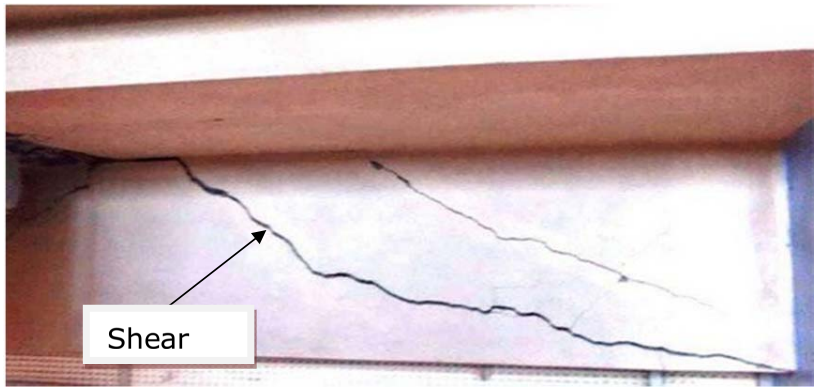
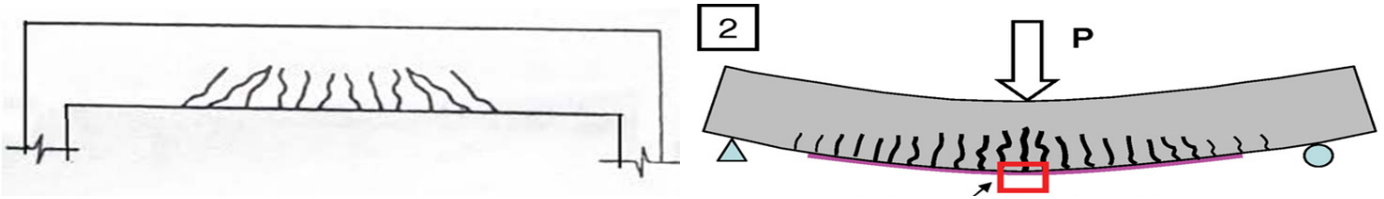


Fig no.1 Shear Crack

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
RC Beam	Shear	This type of cracks occurs near to the supports of the beam. Generally the cracks occur in 45º or diagonal in manner. It is a serious structural active crack.	Shear capacity of the beam is inadequate. Cross-section or stirrups are insufficient.	Provide lateral ties / stirrups with adequate nos. and spacing.	Chip the concrete and place the new stirrups with required spacing and apply expoy and then apply fresh concrete. After concrete gets harder apply epoxy and paste carbon fiber sheets.

Flexure cracks:



Member	Crack Type	Important Characteristics	Cause /Reasons	Prevention	Solution
R C Beam	Flexure	These cracks form at the bottom near the midspan and propagate upwards. May be single or in groups of cracks.	The Tension occurs at the bottom of the beam.	Provide adequate reinforcement at tension zone.	Chip the concrete and place the new reinforcement with required nos. at the bottom and apply expoy and then apply fresh concrete. After hardening paste carbon fiber sheets.

Fig no.2 Flexure Crack

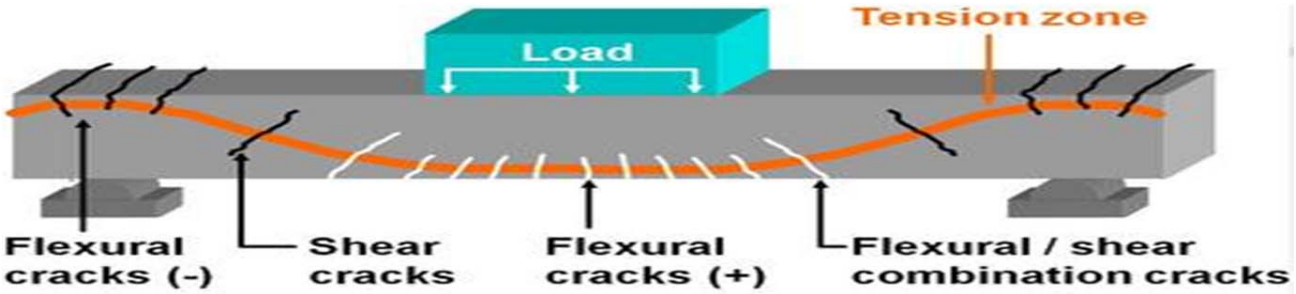


Fig no.3 Cracks On Beam

Combination of flexural and shear cracks

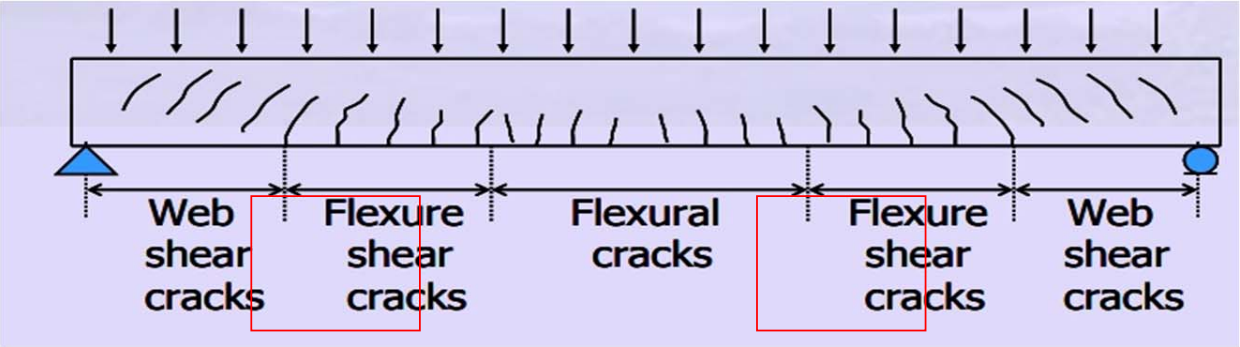


Fig no.4 Combination of Flexure-Shear Cracks

Member	Crack Type	Important Characteristics	Cause /Reasons	Prevention	Solution
R C Beam	Flexure-shear cracks	This crack occurs at the bottom due to flexure zone and propagates on both flexure and shear areas.	Inadequate shear capacity and tension bars in the beam. In this zone deflection curve takes place.	Provide adequate tensile reinforcement at tension zone and Provide adequate stirrups to resist the flexure-shear cracks.	Chip the concrete and place the new reinforcement and stirrups with required nos. at the bottom and apply expoy and then apply fresh concrete. if possible apply epoxy and paste carbon fiber sheets

TORSION CRACKS

Fig no.5 Torsion Cracks

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
R C Beam	Torsion	Originates nearer to maximum torsion region. Generally uniform width. Appears over the whole periphery of beam.	Torsional strength of the beam is inadequate.	Provide torsional, shear and side reinforcement .	After removing the concrete use extended U-jacket or steel plates, CFRP, GFRP laminates around the cross section to a depth equals to one-sixth of the beam width along the whole span and then replaced with new concrete

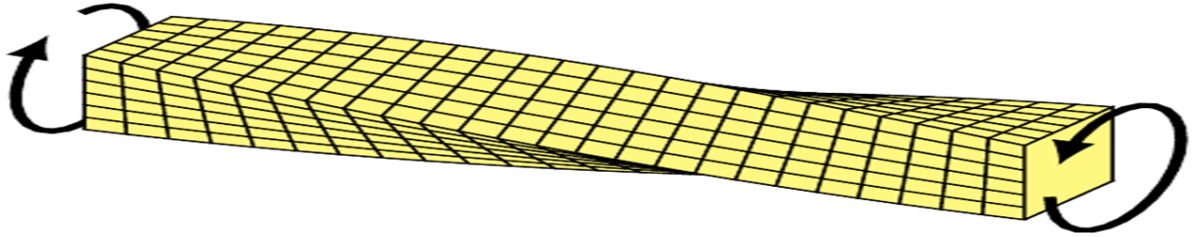
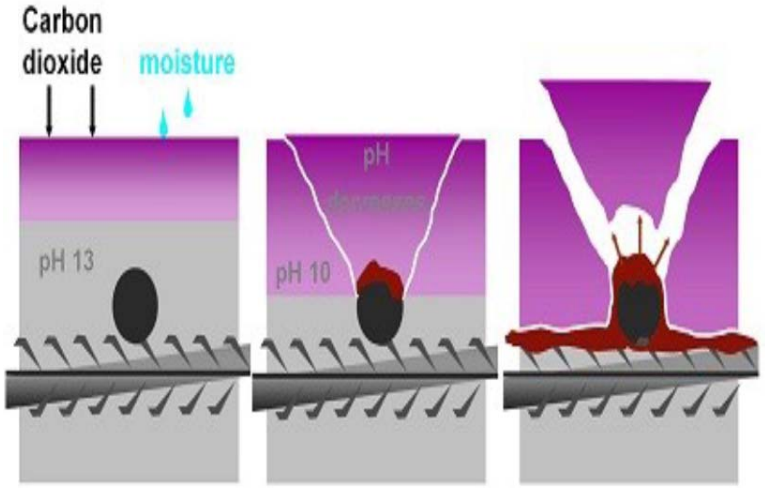


Fig no.6 Torsion on Beam

CORROSION CRACKS



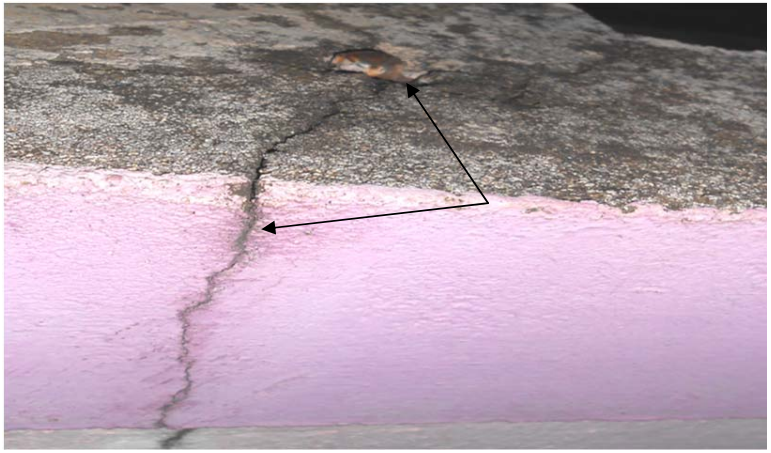


Fig no.7 Corrosion Cracks

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
R C Beam	Corrosion crack	Runs above the line of reinforcement or parallel to the reinforcement.	Bond between reinforcing bars and concrete not satisfactory, due to corrosion of bars.	Use corrosion resistant bars. (OR) Epoxy coated bars (OR) Use good grade of steel.	Remove the concrete and clean the corroded rod and attach new rods and apply expoy and fresh concrete.

Fig no.8 Corrosion Cracks on beams

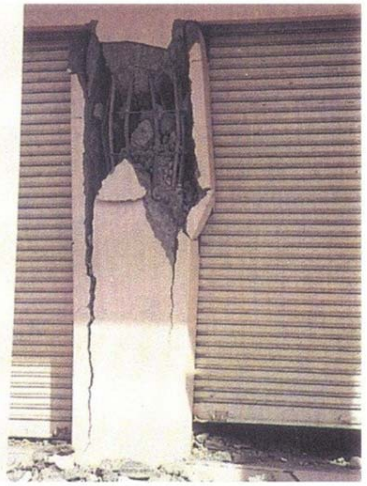
SHRINKAGE CRACKS

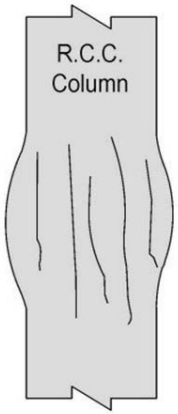
Fig no.9 Shrinkage Cracks

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
Slab, beam, column	Shrinkage	No regular pattern or thickness and in general.	Curing is inadequate or no control over water-cement ratio. Usage of excessively rich mix.	Do proper curing with equal intervals. Use proper W/C ratio.	Do cement plastering or petty on the members.

CRACKS IN COLUMNS

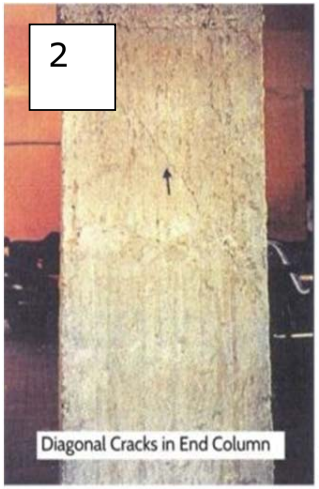
1





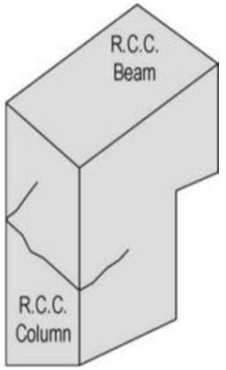
Splitting Cracks

2



Diagonal Crack

3



Horizontal Crack

Fig no.10 Cracks On Column

Fig. No. 10	Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
1	R C Column	Splitting	Short parallel vertical cracks. Varying widths. Bulging in that region.	Load carrying capacity of the column inadequate. Inferior quality concrete.	Provide sufficient reinforcement in the column and right mix of concrete.	Remove the surface concrete and clean the corroded rod and attach new rods (extra rods) and apply expoy to the rods and then apply fresh concrete. After concrete hardens, apply epoxy paste and Then wrap the column with carbon fiber sheets
2	R C Column	Diagonal	Runs diagonally across the section. Can occur anywhere in the height. Uniform thickness.	Load carrying capacity of the column is inadequate, main reinforcement is insufficient.	Provide sufficient reinforcement in the column.	
3	R C Column	Horizontal	Occurs near beam-column junction.	Moment resistance capacity of column inadequate in the corresponding region inadequate quantum of reinforcement or disposition of reinforcement not satisfactory	Provide sufficient reinforcement in the column and close spacing stirrups.	

Note: One can use other fiber sheets for wrapping on column, with good stiffness and tensile strength property.

Fig no.11 retrofitting of column jacketing followed by using carbon fiber sheets

Vegetation cracks

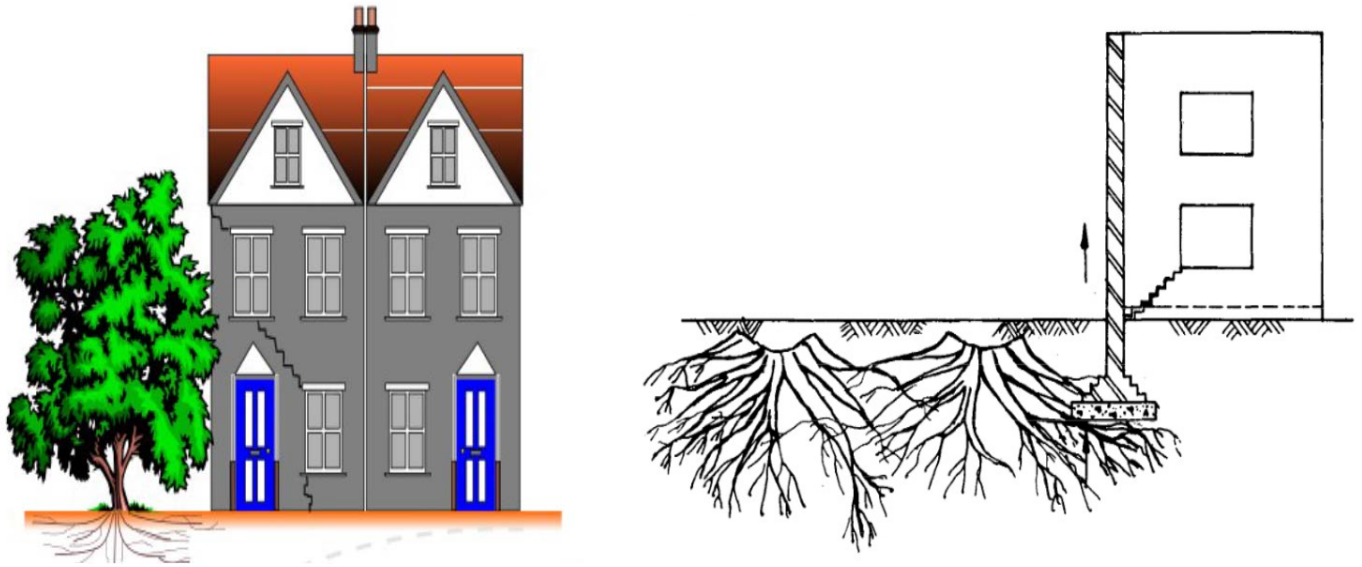


Fig no.12 Vegetation Cracks on beams

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
Footing	vegetation cracks	Fast growing trees near the footing can sometimes cause cracks in walls due to Expansive action of roots growing under the foundation.	Expansive action of roots causes the cracks on the walls	Remove the trees or sapling which is near the footings.	Remove the tree and replant the trees in some other location.

Fig no.13 Tree Replanting

Crack on walls :

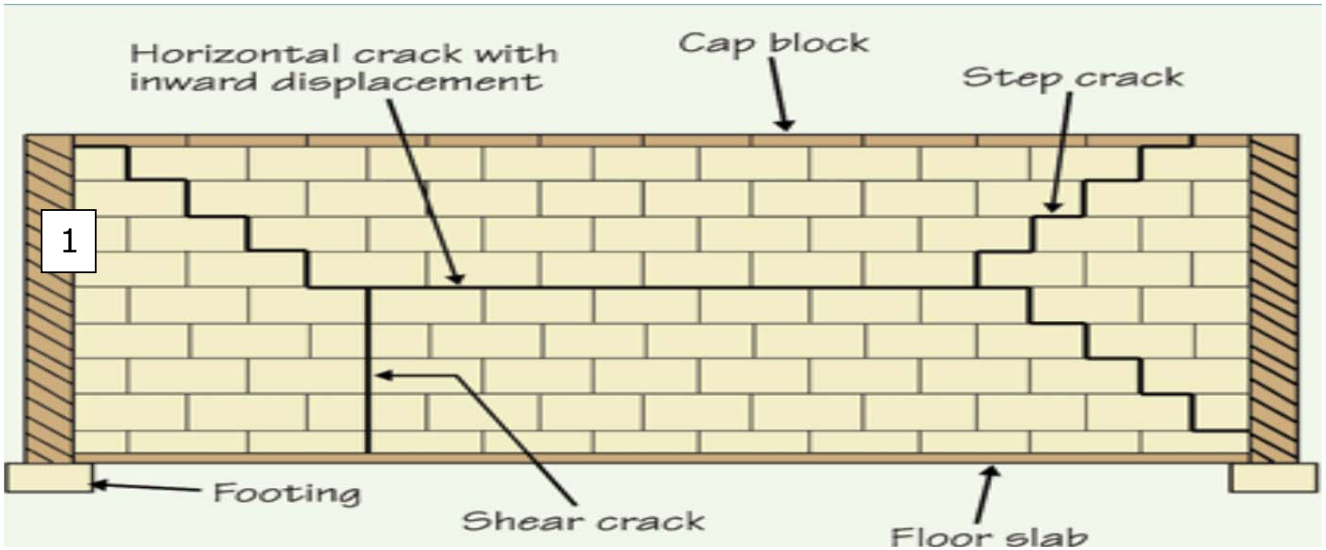


Fig no.14 Cracks On Walls

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
Wall	Step crack	Crack occurs step by step from upward or downward. Crack occurs in the mortar and continues from one layer to another mortar joints.	Foundation settling And soil settling at the centre of wall, differential settlement.	Provide proper compaction and layers of sand filling followed by P.C.C and Provide sufficient mortar thickness in brick joints.	Place mortar in the gaps and rework the wall. Place vibrator and settle the soil equally. In some cases reconstruction of wall has to be done.

Fig no.15 Horizontal Crack

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
Wall	Horizontal crack	Crack run in horizontal direction through the mortar	Crack means serious problem such as severe foundation shifting/settling or poor water drainage.	Provide proper compaction and layers of sandfilling followed by p.c.c and Provide sufficient mortar thickness in brick joints.	Place mortar in the gaps and rework the wall. Place vibrator and settle the soil equally. In some cases reconstruction of wall has to be done .

Fig no.16 Sill Level Crack

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
Wall	Sill level crack	Cracks occurs at the corners of the windows	Due to tension at the window opening's at corners. If it is wood , swell during rainy season.	At the sill level, in window opening's by 1 feet on each side provide the mini. Size steel rods with wire mesh or chicken mesh and apply concrete on it	Apply Crack filler/Stitching with steel rods

Horizontal Crack On Parapet Wall

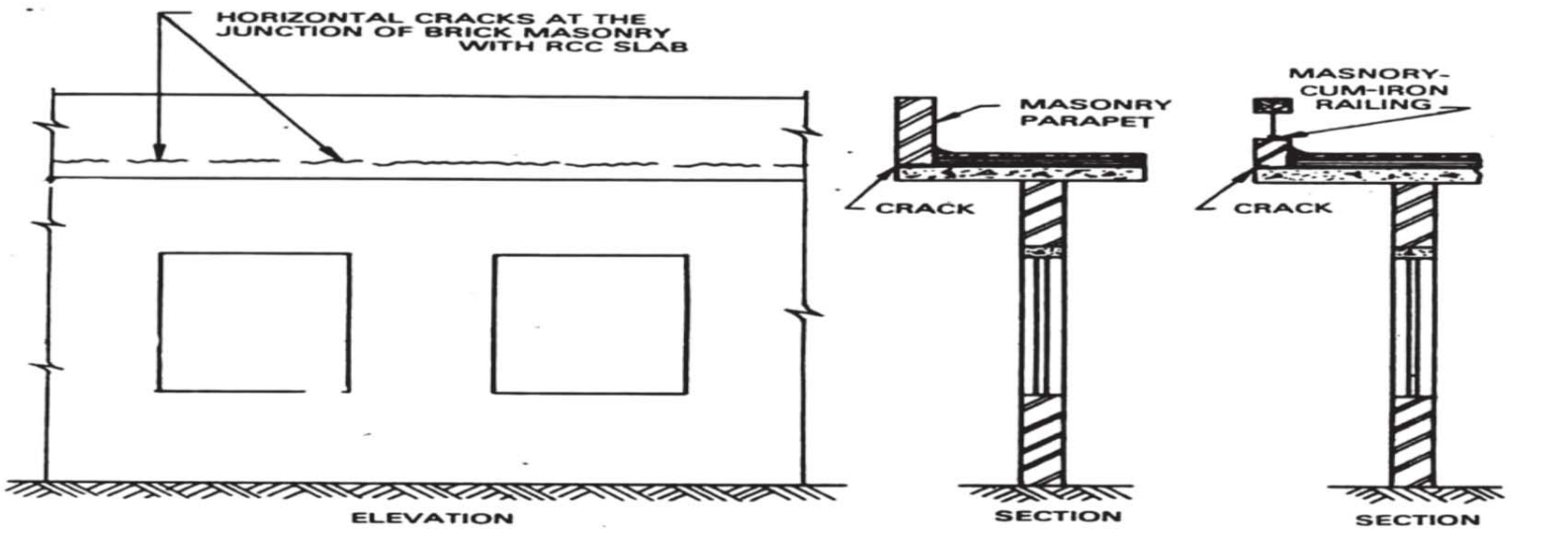


Fig no.17 Horizontal Crack On Parapet Wall

Member	Crack Type	Important Characteristics	Cause -Reasons	Prevention	Solution
parapet wall	horizontal crack	Crack run in horizontal direction of parapet wall.	cracking due to thermal movement in buildings	Roof Slab conc may be bent for about 230 mm vertically	Apply Crack filler/Stitching with steel rods

Efflorescence on walls:

Fig no.18 Efflorescence On Walls

Member	Type	Important Characteristics	Cause / Reasons	Prevention	Solution
Wall	Efflorescence	White patch on the walls	Presence of salts is white patch due to dampness , poor of quality bricks	Use good quality of bricks and water proofing spray on wall.	Clean the Efflorescence with wire brush and apply water repellant coating on them or paint the walls.

Efflorescence on concrete:

Fig no.19 Efflorescence On Roof Slab

Member	Type	Important Characteristics	Cause / Reasons	Prevention	Solution
Slabs	Efflorescence	White patch on the slabs	Presence of salts is white patch due to water leakage from the terrace, poor quality of weathering floor.(permeable in nature)	Provide right mix of concrete and water repellant coating on the top surface of terrace slab, to prevent below roof slabs from dampness/	Clean the Efflorescence with wire brush and apply water repellant coating on the top surface of terrace floor.

METHODS TO MONITOR & MEASURE THE CRACKS :

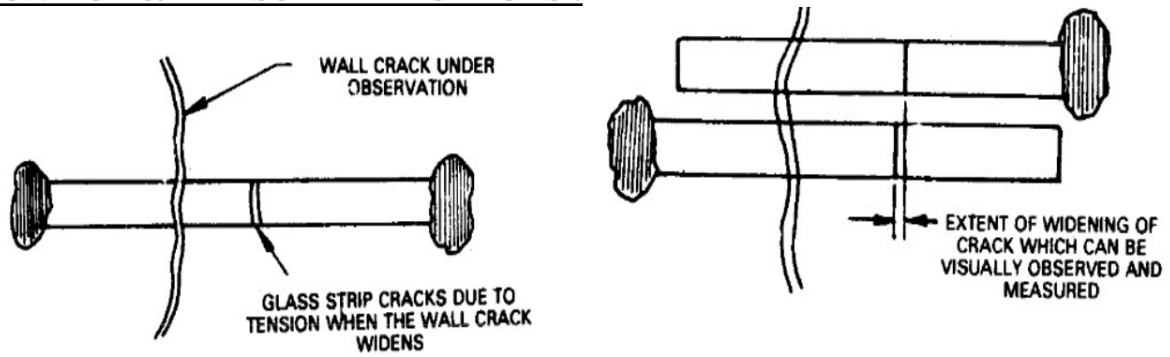


Fig no.20 Measuring Cracks

PLACING	HOW IT WORKS	RESULT
A commonly used method of doing so is to fix tell-tales consisting of strips of glass about 2 to 3 cm in width an 10 to 12cm in length across a crack with some quick setting, mortar or adhesive.	i) If the crack widens, the tell-tale will crack. ii) In case the crack closes instead of widening out, the glass strip will either get disjointed at one end or will crack by buckling. iii) If NO changes occur , appears as it is.	i. Active crack ii. Settlement and movement of soil leads, close the crack. iii. Dead crack

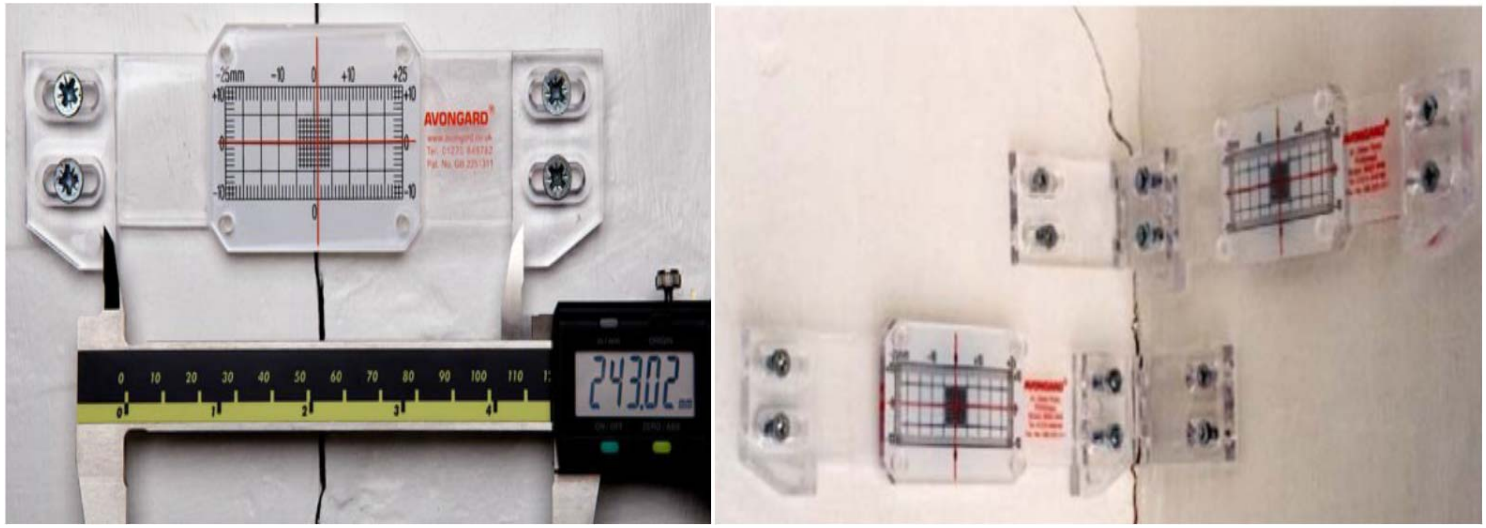


Fig no.21 Measuring Cracks Device

Used for monitoring measuring and recording the crack width of a building structure. Internal or external use, material is vand resistant polycarbonate. They are suitable for vertical, horizontal and vertical movement measurements.

The high precision calipers are used to measure the width of cracks.

Cracks on wall joints

Fig no.22 Cracks On Wall Joints Of RC Members

Member	Type	Important Characteristics	Cause / Reasons	Prevention	Solution
Brick Wall-RC Beam	Joint crack	Crack in the junction of Brick Wall- RC Beam	No joint connection / bonding between them	At the bottom of the beam , make chipping marks on them. Place mortar on the each bricks and lay them.	On the cracked surface , chip the brick wall and place 6mm rod of 1m of required interval spans and place mortar with rich mix.
Brick Wall- RC column	Joint crack	Crack in the junction of Brick Wall- RC column	No joint connection/ bonding between them	At the side of the column , make chipping marks on them. Place mortar on the each bricks and lay them .	On the cracked surface, chip the brick wall and place 6mm rod of 1m of required interval spans and place mortar with rich mix.

CHAPTER - X

FOUNDATION IN BUILDINGS

- Tid bits for Field Engineers

Foundation or sub-structure is that part of the structure, which lies buried in the ground, and it supports the superstructure, i.e. the visible part of the building under usage. All vertical elements like columns and walls will be provided with footings, which will spread load to the supporting soil, in such a way, that the pressure on soil remains within the allowable pressure of soil and also the settlement of footings remains within the allowable value of settlement of soil.

The type of foundations to be provided depends on the following factors.

1. Type of soil
2. Type of loads
3. Type of structure
4. Economy
5. Permissible Differential Settlement

The common type of foundations used in practice are, Conventional footing, Isolated footing, Combined footing, Strip footing, Raft foundation, Pile foundation etc.,

ISOLATED FOOTINGS:

The most economical footing type is an isolated footing. It is therefore recommended to have isolated footings for columns wherever possible.

All footings are to be tied by grade beam. Exterior wall grade beam must be 30cm below the formed ground level. Interior grade beams may be at the same for exterior wall or other wise at plinth level. Considering effective filling in basement, the width of filling may be restricted to about 6m by providing interior grade beam below ground level.

The Design of Grade beam taking 15 kN / m (max weight of one storey masonry wall) and the BM as wl^2 / 24, same reinforcement may be provided at top and bottom.

Generally isoloated footings are not designed for any moment since the footing are tied in two principal directions by Grade beams and the footing rests on soil, which is an elastic medium. Ready reckoners for Isolated footing design are enclosed in chapter I.

1. COMBINED FOOTINGS:

When the adjoining isolated footing overlap combined footing for the adjoining two columns is the most economical solution. Combined footing is having a beam connecting the two columns. Generally more or less equal load columns are to be combined together to avoid long cantilever beam. Combined footings are also adopted for the columns in property line.

3.STRIP FOOTINGS:

The Strip foundation is the extension of a Combined footing for a row of columns. The central beam is to be provided with cantilever slab on either side of it.

4.RAFT OR MAT FOUNDATION:

When the bearing capacity of the soil is very low, it is not possible to provide isolated footings under individual columns. The types of foundations suitable in such soils are raft or mat foundation and pile foundations. When the bearing strata is not very deep in such soils, raft or mat foundations are economical.

A raft or mat foundation is a thick reinforced concrete slab provided to cover the entire foundation area under a number of columns.

Lift pit may be designed as raft slab with RCC wall so that the pit is watertight.

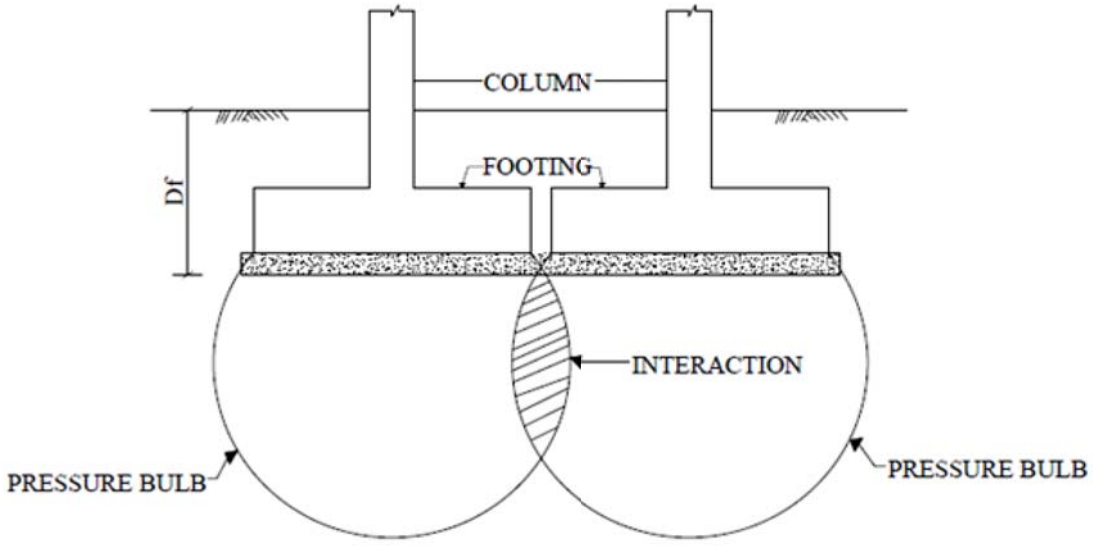
ECONOMICAL FOUNDATION

Soil investigation report gives the net safe bearing capacity of soil, which is calculated from the ultimate soil bearing capacity, by using a factor of safety of 3.0 to 2.5.

(The practice of taking 10% extra load for self weight of footing is not followed by few Engineers, as the weight of the footing only displaces the weight of the earth excavated. The column or wall load without any extra increase can be considered for calculating footing area. This is made clear in the clause 5.2 of IS: 1904-1978.However it is left to the discretion of the designer.)

The most economical footing type is an isolated column footing. It can be made of uniform depth or sloping depth or stepped depth. “Bowles” has advocated use of isolated footings, even when one footing just touches another one.

But in some old texts, one comes across a statement, that when isolated footings occupy more than 50% of the floor area of building, a raft foundation should be used. this becomes a costly proposition. When the isolated footing are put side by side, bulbs of pressure will interact, this effect will slightly reduce the factor of safety of 3.0 to 2.5 to, say, a value of 2.8 to 2.3, which is still quite adequate. It is therefore, recommended to have isolated footings for columns, wherever possible.



Interaction of Pressure Bulbs

DEPTH FOUNDATION

The depth to which foundation should be carried depends upon following factors.

1. The securing of adequate bearing capacity.
2. In case of clay soils, penetration below the zone where shrinkage and swelling due to seasonal weather changes are likely to cause appreciable movements.
3. The maximum depth of scour wherever relevant shall also be considered and the foundation should be located sufficiently below this depth.
4. The minimum depth of foundation below the existing ground is 0.6m. It is important to bury fully the footings in the ground.

   If the footing depth is 0.30m, with 100 mm of lean concrete and 150 mm. of earth cover on top of footing, the foundation depth (Df) works out (Fig below.)

   Df=0.15 + 0.30+0.1=0.55 or 0.60m.
5. But in practice, the foundation depth is kept at 0.9m or even more.

Important point on Depth of foundation:

Minimum depth of foundation: 500 mm from G.L. (As per I.S. 1080-1962)

Minimum depth of foundation as per Rankine's theory

$D = p / \gamma \{1- \sin \varnothing / 1+ \sin \varnothing \}2$

Where p = gross bearing capacity (SBC)

γ = density of soil.

$\varnothing$= angle of repose of soil.

But in practice, the foundation depth is kept at 0.90m or even more.

The depth of foundation depends not only on the nature of soil strata but also on the height of building. It is customary practice to place the foundation of a "simple footing " at a minimum depth of 1.50 m from ground level or at least 1.50 times the width of footing.

In cold climates the depth is kept at a minimum of 1.50 m below surface because of possible frost action.

For low rise building (less than four storeys) a depth of foundation of 1.2m to 1.50m may be adequate.

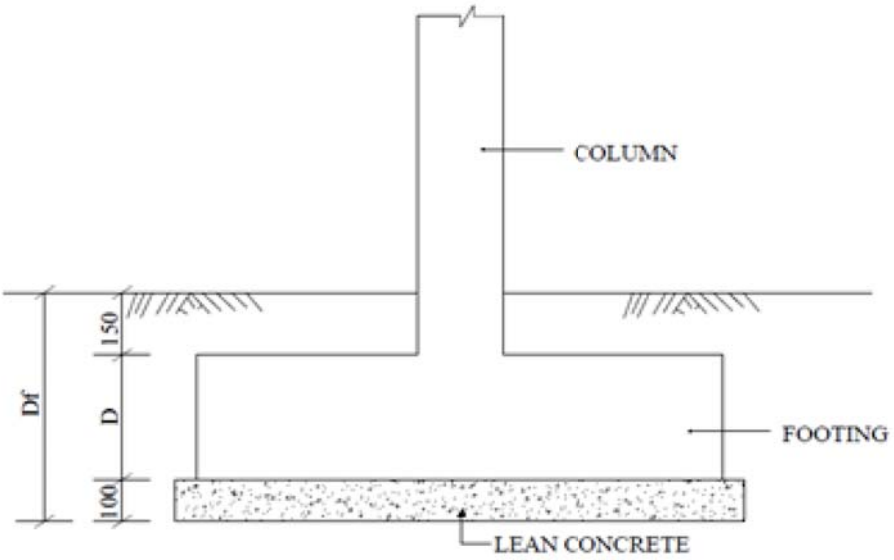
For taller buildings (6 to12 storeys) 2.0m to 3.0m foundation depth will be adequate.

For still taller buildings shallow foundation may not be suitable. In these case higher capacity pile foundation shall be adopted to suit the super structure of load and nature of soil condition.

For tall isolated Structures, like water towers, the foundation depth may be at 3.0m.

A few practical requirements also may have to be considered while deciding the depth of foundation such as the existing foundation of nearby building, the possible influence of future expansion etc. If the height of building is more, the horizontal forces acting on the building such as wind force are large. As a thumb rule, minimum depth of foundation may be selected as 5% to 10% of the height of building.

Where the moisture content may vary and cause shrinkage, the depth must be considered with the minimum moisture content variation(1.50m to 2.0m).In case of black cotton soils of expansive nature, the zone of movement may be as deep as 3.0m to 3.50m. This is why, the under reamed piles in expansive clays are taken to minimum depth of 3.50m.



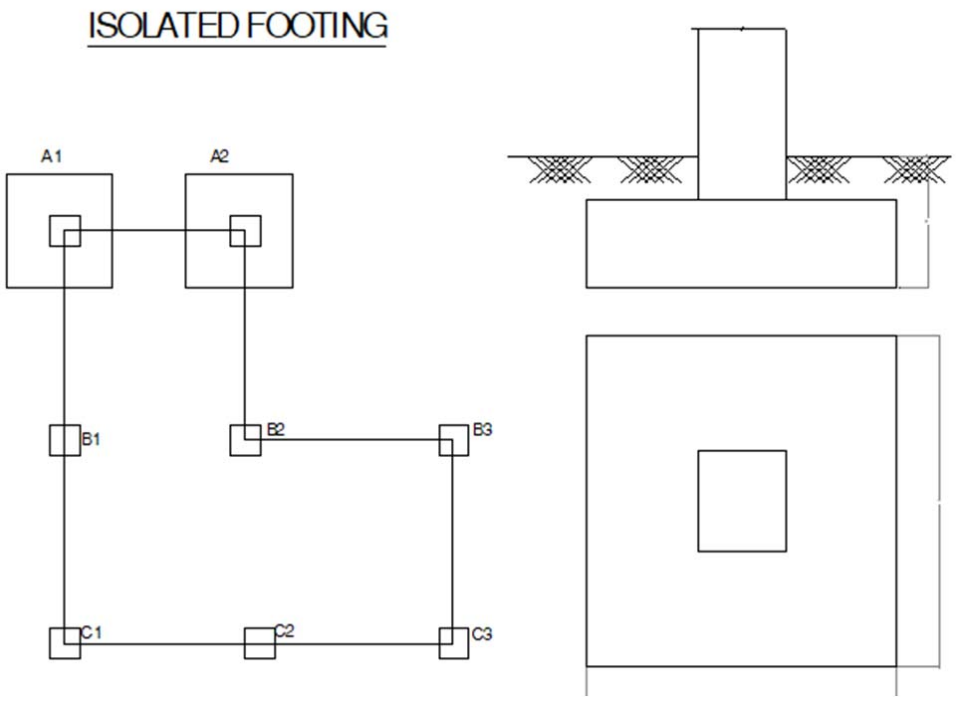
CHOICE OF FOUNDATION

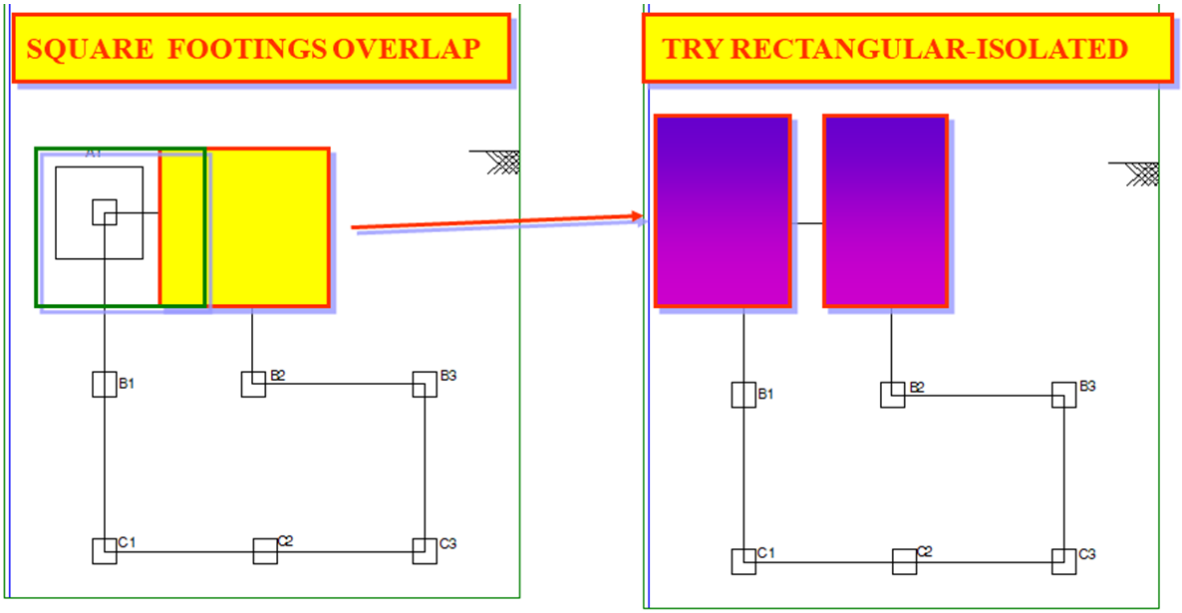
When the adjoining isolated square footings overlap, rectangular footings will be the next choice. If it is not possible to provide square footing, try to provide rectangular footing. Rectangular footing may be provided up to L/B ratio is less than 1.5. If it is not possible then combined footing is to be adopted

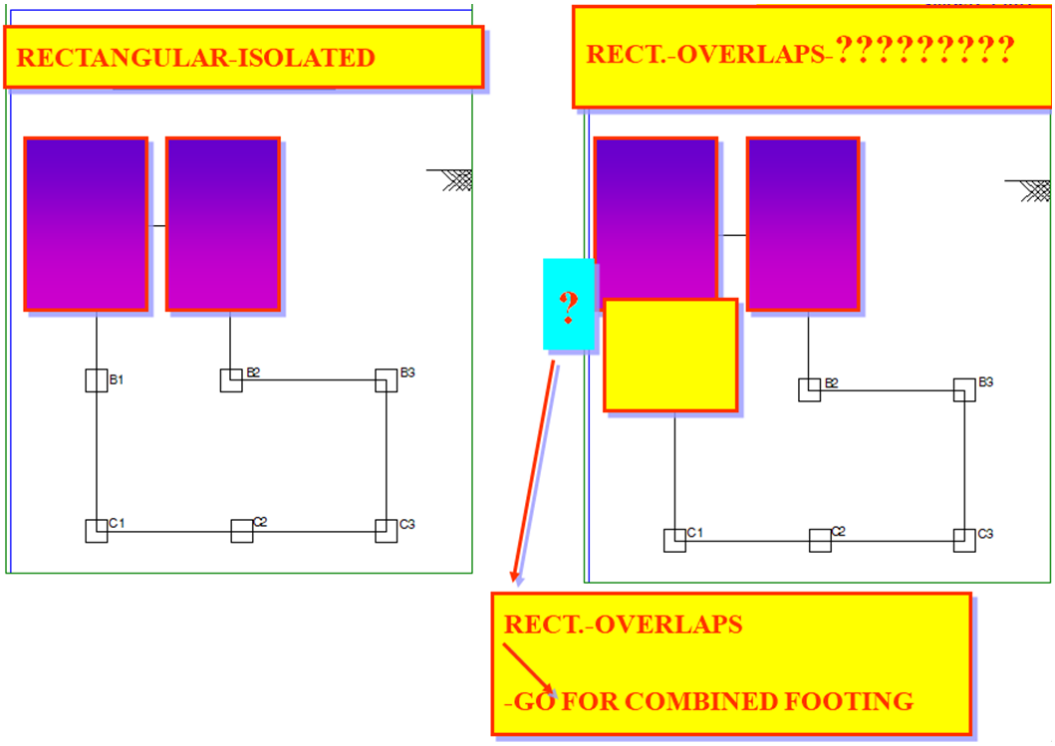
So when rectangular isolated footings also overlap, a combined footing for the adjoining two columns is the next economical solution.

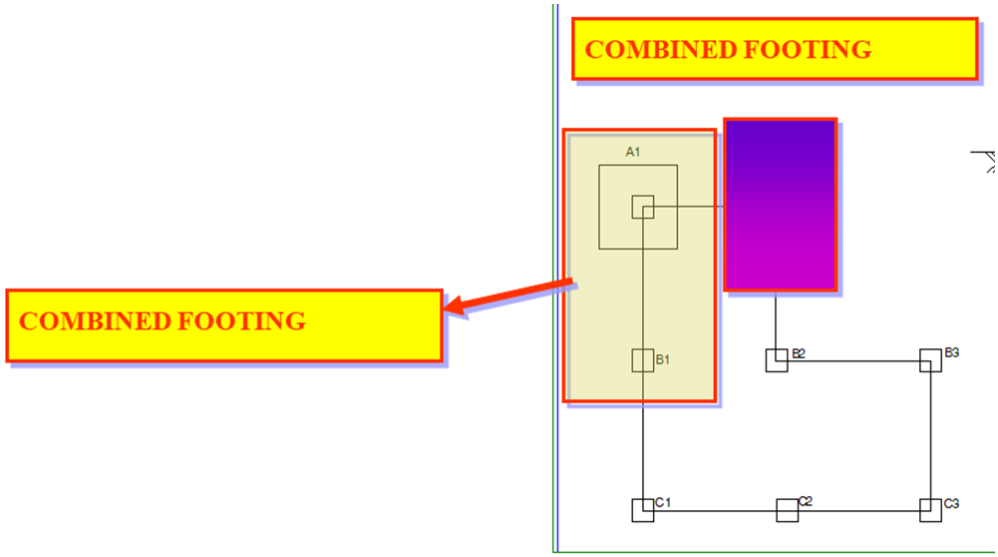
A strip foundation is the extension of combined footing for a row of columns. The central beam is to be provided with cantilever slab on either side of it.

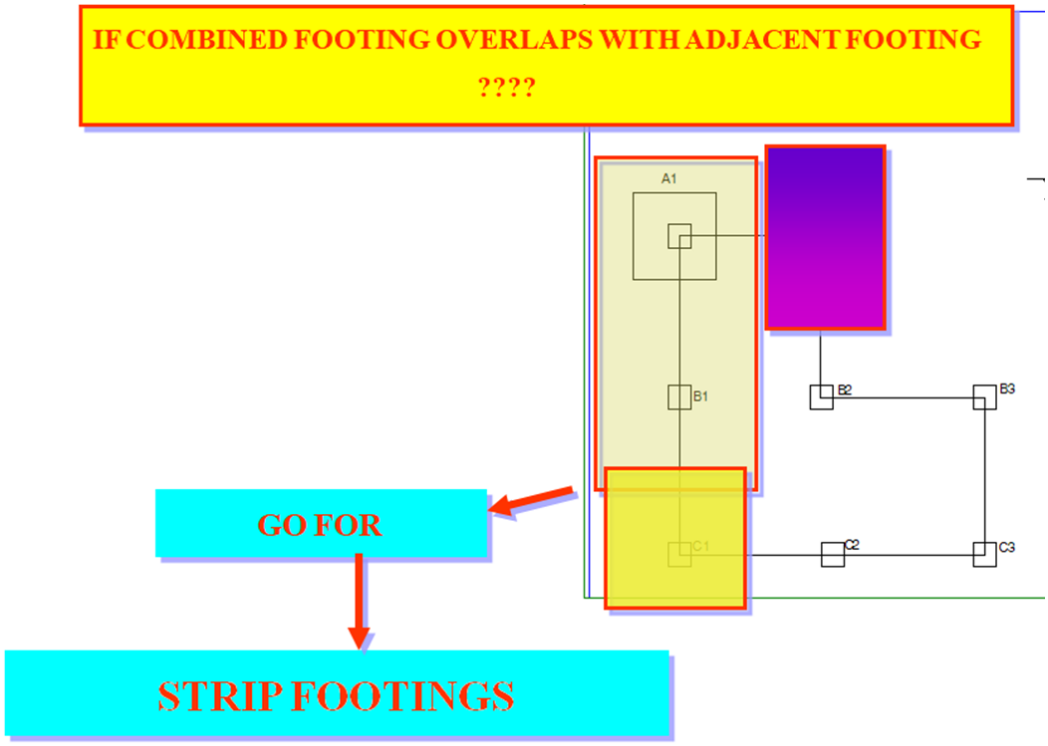
When the strip footing overlap, it leads to a raft foundation. Initially, one tries to provide a few small-area rafts as this leads to economy. But a situation may arise, when one single rart covering all the columns of building may have to be provided. This is a costly proposition, but it has to be adopted, as other less costly altematives have already been examined and rejected for the various difficulties. A slab type raft is commonly adopted, for ease in design and construction, but it consumes more steel. Beam-slab type raft saves steel but requires more depth of foundation.

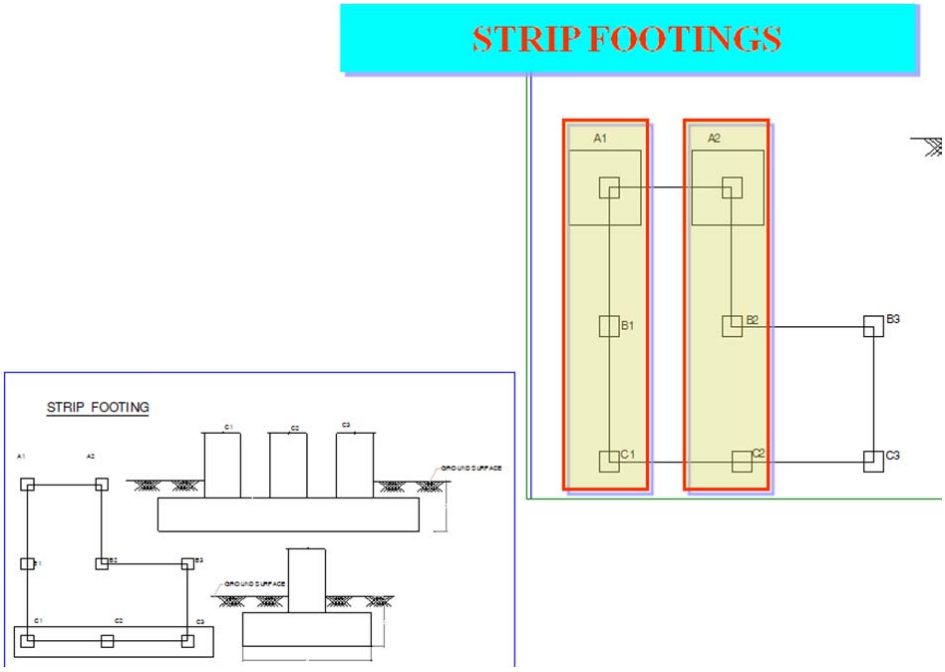


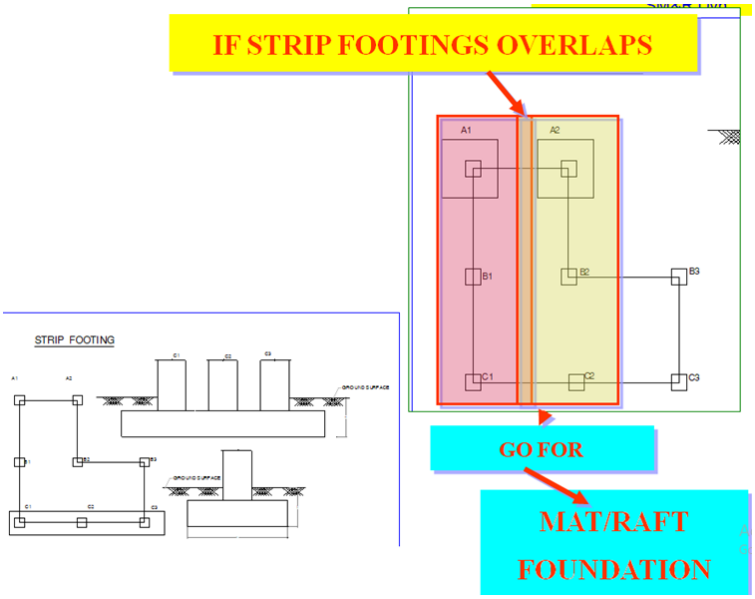










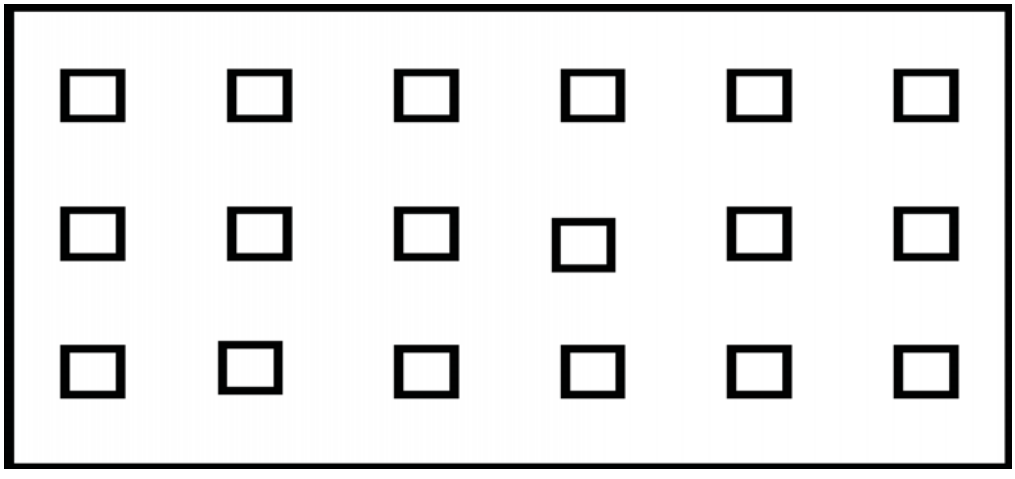


Mat foundation

The is provided

1)when the soil is having very low bearing capacity and /or

2) when columns loads are heavy, the required footing area becomes very large and uneconomical.

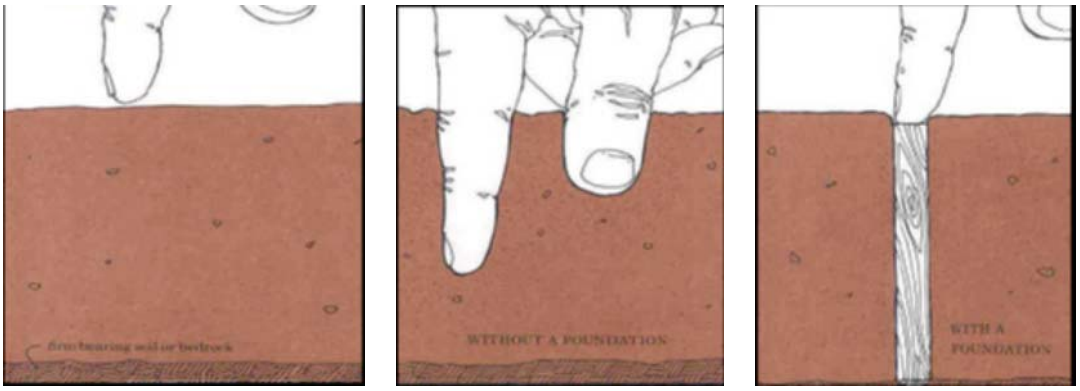


Mat foundation

PILE FOUNDATION

Pile foundations are the part of a structure used to carry and transfer the load of the structure to the bearing ground located at some depth below ground surface.Piles are long and slender members which transfer the load to deeper soil or rock of high bearing capacity avoiding shallow soil of low bearing capacity. The main components of the foundation are the pile cap and the piles. The main types of materials used for piles are steel and concrete.

Fundamental Concept of Pile Foundation

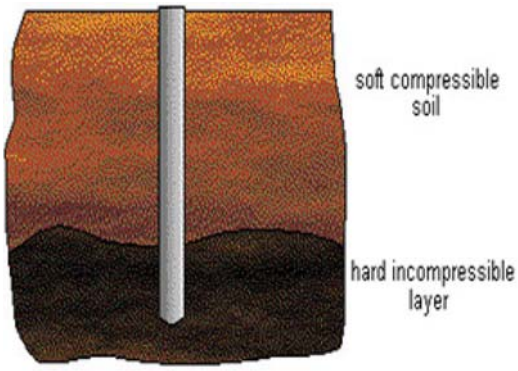


Classifications of piles with respect to load transmission and functional behaviours :-

1. End Bearing Piles (point bearing piles)
2. Friction piles (cohesion piles)

Classifications of piles based on method of erection

- 1) driven cast in situ concrete pile
- 2)bored cast in situ concrete pile
- a)cased pile
- b)uncased pile
- 3)driven precast concrete pile

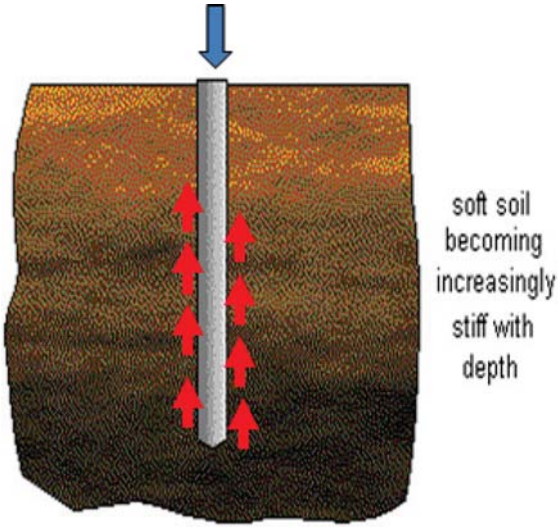


END BEARING PLIE

- The load of structure is transmitted to that hard layer of soil/rock
- Hard strata available at reasonable depth
- Pile driven up to hard, impenetrable layer of soil/rock

FRICTION PILE

- The load of structure is transmitted by skin friction or by adhesion between the surface of the pile and adjacent soil
- Hard stratum not available at reasonable depth



FOUNDATION FOR EXPANSIVE SOILS

If the soil is expansive in nature, lot of care is to be taken.

How to identify Expansive Soil ???

1. Are the soils nearby the project area known to be expansive?
2. Are there evidences of cracks in walls, curbs, sidewalls, pavements etc. in nearby construction?
3. Are there shrinkage cracks in the soil (in dry season)?
4. Does the soils behave as a very sticky soil, sticking to shoes, tyres etc. when wet?
5. If you take a lump of dry soil and try to break it between fingers, do you find the soil hard and difficult to break?
6. If you select a large lump of dry soil (say about one kg) and raise it chest high and drop it on hard surface (pavement), does the soil stay as lump (s) without breaking up into a number of small pieces? (Breaking of thin edges or sharp corners or breaking into 2 or 3 major pieces because of existence of shrinkage cracks shall be discarded).
7. If you take (or make) a wet soil with moisture content that would permit easy moulding with light finger pressure and then remould and roll it to threads of approximately3mm in diameter, can a thread, a few cm. long, stand on its own weight when held down at one end?
8. If you make a uniform paste of soil and water (water content should be almost same as item 7 above) on the palm of your hand and strike the lower part of your hand against the other hand in rapid but short strokes (5 to 8 cm long) for 10 to 15 times, does the soil look almost the same as when you started without shiny surface?
9. If you take a ball of wet soil (similar to that in item 8 above) and drop it on a piece of smooth, dry glass plate from a height of about 45 cm and turn the glass upside down (soil towards ground), slightly tilted and tap the top of the glass with your finger tips, does the soil remain stuck. If the original position on the glass instead of falling off or sliding?

Note: A yes answer to any of the above question may indicate an expansive soil and need for further testing and study.

UNDER REAMED PILE:

When the soil is expansive in nature like black cotton soil, under-reamed piles are adopted.

For the past 40 years under reamed piles are being used for residential buildings. This type of foundations have also failed in many cases, due to failure of grade beams. The grade beam should not have contact with soil and this can be achieved by providing wedge on one side and brick on edge in other side. But a complex nature of construction requires more skill and attention. The floor may sink and there is a possibility of small creatures to enter in to the building through the gap below such grade beam. This is also costly. Moreover the grade beams are designed for very very less bending moments of $(wl^2 / 30)$ or $(wl^2 / 50)$ as given in undreamed pile code.

However if the grade beam is designed for uplift swelling pressure, this type of foundation may be used, since the uplift pressure s high in the order of 200 kN / Sq.m.

RESTRICTIONS:

1. This type of foundation is suitable only for residential buildings. For other type of building this is costly since pile caps are to be provided to transfer load to group of piles.

2. In some soils forming of under-ream is not possible.

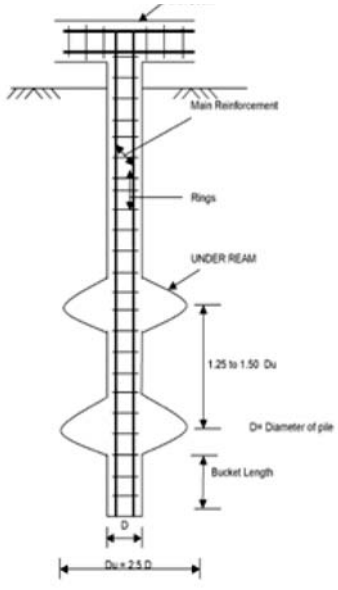
3. If water level is up, drilling and concreting is not easy.

4. It is not 100% sure of perfect concreting. Necking may be formed in the pile and strength taken is less.

Capacity of Under Reamed Piles (3.50m)

(IS 2911-Part III. Developed by CBRI)

Dia	Capacity
• 300 mm (4-12T)	160 kN
• 375 mm (5-12T)	240 kN
• 400 mm (6-12T)	280 kN
• 450 mm (7-12T)	350 kN
• 500 mm (9-12T)	420 kN



Under reamed pile with two under reams

STUB COLUMN ARRANGEMENTS:

For ordinary small buildings, Stub column arrangement with strong grade beams is well suited for expansive clay. Here load is concentrated on the column footing and the uplift will be less.

PRECAUTIONS:

1. If foundation is designed for three storey and present construction is one storey, then more contact is available for uplift. Then cracks will develop. Hence only one storey may be provided future construction.
2. Correct SBC is to be ascertained for this type of soil. Out of fear or otherwise if very less SBC is assumed then, large contact area is made available and cracks will develop.
3. Corner stub columns may be rised upto roof level so that cracks formed due to torsional effect will be avoided.

PRECAUTIONS FOR THE FOUNDATION IN EXPANSIVE SOIL:

1. Pavement of minimum 2m width may be provided alround the building. Pavement may be of brick jelly concrete over any type of impervious layer.
2. Trees should not be within 8 metres from the building.
3. If the soil is of highly expansive, structural slab may be provided for flooring and reinforcement may be provided at the mid depth of the slab.
4. As for as possible try to avoild light load structures, if lighter structure is constructed more precautions are to be taken.
5. For basement filling expansive clay should not be used. Top soil of minimum 15cm it to be removed and refilled with good earth. Below footing minimum 30cm non-cohesive soil may be provided.

GRADE BEAMS FOR FRAMED STRUCTURE IN EXPANSIVE SOILS

The Grade Beam is the most vulnerable member in the structure. Here also the Grade Beam should not have contact with soil. Generally upward soil selling pressure is 100 to 400 kN/m^2. If it is not possible to provide Grade Beam not in contact with soil, the grade beam should be designed with average uplift pressure of 200 kN/m^2. Upward Pressure = 200x0.23 = 46 kN/m.

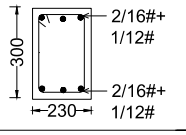
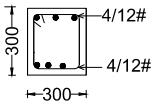
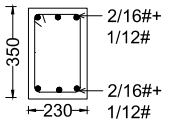
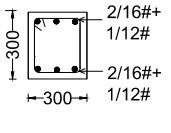
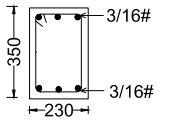
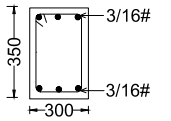
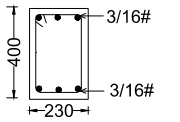
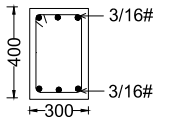
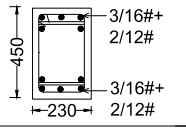
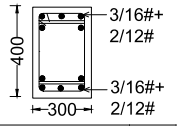
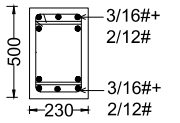
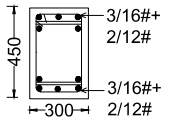
The Bending Moment is calculated be using the following formula.

B.M. = $wl^2 / 16$

Same reinforcement should be provided at both top & bottom .

If there is a full brick wall with load of 15 kN/m. the grade beam may be designed for the upward pressure of 31 kN/m. (46-15=31) only.

Grade Beams For Framed Structure In Expansive Soils

	Span in m.	GRAVITY DESIGN	SEISMIC DESIGN	REMARKS
1	3.00 to 3.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
2	3.50 to 4.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
3	4.00 to 4.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
4	4.50 to 5.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
5	5.00 to 5.50 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	
6	5.50 to 6.00 m			
		STP.2L-8# @ 200 mm c/c	STP.2L-8# @100- 200 mm c/c	

LAYING FOUNDATION CONCRETE BELOW WATER TABLE:

In practice quite often foundation pits are excavated and kept open for long for various reasons, which is highly undesirable. The foundation pits may be excavated about 30cm less than desired depth and this layer may be removed at the time of laying foundations. In case, ground water is much above the base of foundation and permeability of the strata is very high, dewatering should be done before laying foundation concrete and dewatering should be continued till the initial setting of concrete takes place.

It is quite often observed in practice that, some place dry mix of cement and aggregate in the foundation pit without mixing water thinking that there is already water in the pit, which is against the principle of concrete making. Concrete drives strength by chemical reaction of cement coat over the aggregates. cement aggregate mixture with a definite water cement ratio should be mixed for prescribed period. In some cases soon after dry mix is placed in the foundation pit water is pumped which naturally carried cement along with it. Backfiring of foundation pits after laying the foundations should be done with earth well compacted.

CHAPTER XI

MAINTENANCE OF BUILDINGS

Introduction

Building maintenance is work undertaken to keep, restore or improve every facility i.e. every part of a building, its services to acurrently acceptable standard and to sustain the utility and value of the facility.

The objective of maintenance is: -

(i) To preserve building and services, in good operating Condition.

(ii) To restore it back to its original standards, and

(iii) To improve the facilities depending upon the development that is taking place in the building engineering.

Inspite of recent improvements in building technology all the buildings deteriorate from the time they are completed. The rate of deterioration depends upon a number of factors.

During the design and construction stages, the following become essential:-

(i) Right choice of material.

(ii) Suitable construction techniques.

(iii) Adequate specifications for construction and installation work.

(iv) Effective supervision throughout construction and rectification of defects.

Where there are inherent defects both in design and construction the maintenance cost rises disproportionately to a higher level and the anticipated life of building is reduced.

Maintenance aims at effective and economic means of keeping the building and services fully utilisable. It involves numerous skills as influenced by occupancy and the performance level expected of a building.

The repair works are classified in under mentioned categories:

(i)Day to day repairs

(ii) Annual repairs

(iii)Special repairs

(i)Day to Day Repairs

Day to day repairs are to be carried out by the Engineers in all the buildings under their maintenance on the basis of day to day observation and complaints

(ii)Annual Repairs

To maintain the aesthetics of buildings and services as well as to preserve theirlife, some works like white washing, distempering, painting, cleaning of lines, tanksetc. are carried out periodically. These works are planned on year to year basis.

(iii) Special Repairs

Such works are undertaken to replace the existing parts of buildings and

services which get deteriorated on ageing of buildings. It is necessary to prevent the structure & services from deterioration and restore it back to its original conditions to the extent possible.

Preventive maintenance

For carrying out preventive maintenance, inspection of building has to be carried out during the months of March-April and September-October.

Two Monsoon winds bring rainfall to Tamil Nadu.

i) South West Monsoon(June-October)

ii) North East Monsoon(November-February)

Experience has taught that monsoon rains, winds and cyclone cause considerable damage to buildings, tall structures, uproot trees and lamp posts, cause floods, roof leakage into buildings, blow water through broken window panels, blow off thatched roofs, hutments and bus shelters, came disruptions in power supply, water supply and sewerage systems resulting in untold sufferings to people besides causing huge financial losses and also endangering lives. To minimize such losses and avoiddanger to life it is necessary to undertake some specific pre-monsoon preventive measures which are briefly discussed below :

Attending to services before Monsoon Rains/Cyclones.

Buildings and Services are to be thoroughly checked for safety and Functioning before monsoon. In coastal areas the same are checked before cyclones.

Precautionary measures are to be taken for various items of the buildings/ services,some of which are mentioned below.

a) Temporary Roofing

Many buildings are provided with temporary roofing like GI/ AC Sheet roofing. Before the onset of the monsoon, the Engineer-in-charge of Maintenance should see that the L/J hooks, bitumen washers, Limpet washers are in position. Precautionary measures against blowing off the roof should be taken by lightly loading the roof temporarily or providing MS flats/ rods fixed by bolts and nuts to purlins for rows of GI/AC Sheets.

b) Door Window glazing :

All broken glazings should be replaced and sufficient number of glass window panes and joinery fittings should be kept in stock for emergency repairs. The tower bolts, hooks and eyes and other wind appliances should be made in working condition.

Occupants should be advised to keep the doors and windows closed during cyclonic weather especially at nights.

c) Checking buildings against seepage

Terraces of all the buildings may be inspected well ahead of the monsoon rains in June and December and necessary repairs carried out. The roofs should be cleaned

and debris removed from the roof to avoid blockages in roof gutters and rain water pipes. Rainwater inlets should be checked and ensured that there are no damages around these.

Vertical rain water pipes should be properly clamped to the walls. Seepage through cracks developed over sunshades is very common. It should be ensured that required repairs are carried out to the junction of sunshades with the walls.

d) Checking of external areas

Open areas and lawns should be inspected and measures taken to ensure that rain-water does not accumulate therein. Storm water drains are under should be desilted and paved surfaces or bunds repaired. Precaution should be taken against erosion of land and embankments.

e) Checking of sewers and sewage installations

All inspection chambers, manholes and sewer lines should be cleaned and flushed to establish free flow of sewage. Sewage sumps should be cleaned of accumulated grit, sand and sludge. Bunds of oxidation ponds should be strengthened wherever necessary.

(f) Checking of electrical installations

Because of rise in ground water table at places, it may be necessary ro remove electric pumping sets installed in wells and sump, below ground water level and raise them temporarily to safe levels.

Care should be taken to ensure availability of standby power supply arrangement to take care of breakdown in power supply in monsoon

or at the time of cyclones. The Diesel Generating sets should be checked and kept inworking condition and wiring should be checked for loose connections.

(g) Checking of Air-conditioning installations

Wherever Central AC plants or package units are provided, the dehumidification system consisting of strip heaters, humidistat etc. should be checked for their functioning.

Post monsoon/cyclone measures

Inspite of pre-monsoon measures taken in various buildings/services, very often these are affected during the monsoon and cyclones.

In coastal or cyclone prone areas, the services are affected more. Immediately after monsoon, all important structures/services should be inspected by a team of engineers from all disciplines concerned with the maintenance and work should be planned to put the services in order immediately.

Overhead cables, uprooted light poles, restoration of power supply, disinfecting of water supply lines/installations, ensuring normal water supply,restoration of sewage pumping operations, flood relief works, repair to breaches to embankments of roads and bunds are some of the important areas which are to be attended immediately after monsoon/cyclone.

Detailed inspection of the buildings should be carried out to ensure that broken false ceiling, broken glass panes, blown off GI/ A.C. sheet roof, cladding, doors and rolling shutters etc, are attended immediately.

REPAIR OF RAINWATER LEAKAGE IN BUILDINGS

Roof drainages of flat and sloped roofs are carried out differently. Drainage of a flat roof requires more attention than that of a sloped roof as any faculty construction can flood the flat roof and lead to leakage and corrosion of steel in the roof slabs in the roof slabs in the long run. Hence attention should be given to proper drainage of these roofs.

Similarly drainage of large sloped areas, as in industrial sheds, should be properly detailed. There are many case histories of very large damages occurring in factories during heavy rains due to faulty design and blocking of drainage pipes due to bad maintenance of roof drainage systems. When repairing for a rainwater leakage, it is the most important consideration to find the exact source of the leakage and then treat it efficiently using the right materials. Rebuilding the structure in the system to prevent leakage is rather costly and in many cases, unnecessary.

Leakage of rainwater in buildings is very annoying and also damaging. It spoils materials and equipments stored in the rooms. Electrical circuits with earth leakage circuit brakers (ELCB) will trip with wet walls. Otherwise the electric leakage in wet walls can give shocks and is dangerous to the occupants. The most important factors in repair of water leakage are the following:

1. The material that is used for repair is suitable for the repair
2. The source of leakage should be carefully identified and rectified.

Material Used for Waterproofing

1. Integral waterproofing compounds
2. Waterproof coatings on concrete with special coatings which with capillary action forms compounds inside the capillaries in concrete.
3. Waterproof coatings such as hot blown asphalt.
4. Membranes with blown asphalt as in tar felt.
5. Elastomeric coatings with elastomeric paints
6. Elastomeric coatings with reinforced fibre of polyester or glass fibre fabrics for crack bridging.
7. Epoxy compounds (such as araldite).

Rainwater Leakages and Their Treatment

The commonly seen leakages and their treatments are discussed further.

Leakage in flat terrace roofs.

The following are the important considerations:

a) All concrete float roofs during construction should be thoroughly cured by pounding water over it. Any leakage noticed at this stage can be rectified easily by cement grouting (by pouring grout of consecutive higher cement) till the leakage stops. Alternately, all the surfaces can be given a coat of hot blown asphalt after curing.

b) The necessary slope for drainage should be provided to the drainpipe points and water should not stagnate at any place on the roof during rains.

c) The necessary fillets at corners, where the horizontal surface nuts a vertical or inclined face, should be provided and water proofed. This item is very important and many leakages along walls are due to defeats at this junction.

d) All the entry points of rainwater drainage pipes should pass through the parapet walls if they are laid beside parapet walls and they should be properly detailed. Entry points should not be blocked with leaves, etc.

e) The water proofing of the roof should be intact and any cracks of exposed surfaces of tiles joints in tiles, joints with other surfaces such as roof and parapet should be properly grouted. If necessary, blown bitumen or elastomeric paints with fibre glass, polyester or other reinforcement to give gap to the crack bridging strength to the coatings.

f) Very porous concrete slabs may have to be grouted under moderate pressure to make it free of voids.

Leakage in sloped roofs and shells:

It is quite common that these sloped surfaces are not compacted properly during construction due to difficulty in compaction. As the surfaces are sloped and the concrete is dense, they tend to drain well during normal rains. However, if the concrete is porous, water can seep through during heavy rains and they tend to leak. This is especially true of valleys of sloping roofs where, unless concrete is well placed, it can become porous

Hence all parts of the sloping roof and in any case, all the valleys should be checked for leakage and grouted at the construction stage itself. As the roofs are usually covered with tiles, it is difficult to repair the roof after construction.

It is advisable at the construction stage itself to apply a waterproofing coating in the form of (plastomeric) bituminous coat or special coating which work on crystallization technique or elastomeric paint coat with fibre reinforcement, if necessary (depending on the state of the concrete). A large number of slope roofed buildings have been found to leak in heavy rains due to lack of this precaution.

In cases where the roof is very porous, grouting with cement grout under low pressure may be necessary. However, these are extreme cases.

Leakage through junctions of walls and sunshades:

This is very common in many buildings and the following items should be checked:

a) Check whether proper slope and drainage have been given at the construction stage. Water should drain away from walls and should not become stagnant in the sunshade. In any case, the architectural features over sunshades should not cause blocking of rainwater flow from the sunshade. (This is common mistake made in many buildings). A throating (or drip course) at the bottom end of sunshades will make the draining water to drip properly.

b) Continuous long sunshades without joints tend to crack at intervals. Water can flow through these cracks and to the walls. Fill the cracks with crack-filling bituminous or elastomeric compounds. All leaves, etc., collected over the sunshades should be removed and sunshades should be kept clean before the rainy season.

Leakage through wall cracks:

The following items should be attended to;

All external cracks in walls should be deepened to 5 mm and filled with paintable sealant. It is also good to paint external walls with special waterproof cement or external paint which can keep the walls waterproof. Silicon paints in walls containing air-conditioning or other electrical connections wills prevent wetting of walls during rains.

Seepage through junction of wall and roof floor slab:

We have dealt with the top of roof slab under 'leakage in flat terrace roofs'. Another important place to check for leakage is bearing on the junction between the roof/ floor slab and the wall- in simple wall and slab buildings as well as in framed buildings. There is a possibility of crack due to expansion of concrete and movement over the wall which will be seen more under roofs than under floors. If there is a crack at this junction at the external face, the water that flows down the wall tends to flow into the building. This can be avoided if during the construction stage itself, a drip course is proved (by extending the slab or constructing a separate drip coarse in framed buildings in the form of a band at that junction).

The old practice of providing bituminous craft paper under the slab on walls is to avoid this trouble. If such leakage occurs in an existing building, the joint has to be sealed with a water proofing sealant or by application of elastomeric paint with glass fibre or polyester fabric reinforcement.

Leakage from external electric points. The conduits laid for wiring for external light fixtures can also form source of leakage of rainwater if they are not sealed properly. Though leakage through these conduits can happen in many unexpected places of the building if they are connected together. All external light points and fittings should be sealed with good sealants and made waterproof.

Joints of slabs and beams. Joints provided by the designer in slabs and beams should be properly filled with approved joint fillers and should be properly installed to allow expansion and contraction of the structure. (Joint fillers are different from sealants.)

CHAPTER XII

DEMOLITION OF BUILDINGS

Structural Audit of Old Structures:

There are number of public buildings which have age of more than 30 years and whose strength might have reduced due to material deterioration. **Based on the yearly tests of each public building to be carried out, the weaker buildings which are more than 30 years old be identified** and the Assistant Executive Engineer level Officer of the department concerned should forward the list to the superior officer of the level of EE/SE. Thereafter, an inspection at the level of Superintending Engineer / EE should be carried out for all such buildings and a thorough structural audit should be undertaken.

The department concerned should consider entrusting the Structural Audit to be also carried out through a suitable Approved Institution / agency and the details of which are suggested as under:

Generally, the Structural Audit is carried out and the steps to be followed in Structural Auditing are as under:

STEP 1:

It is imperative that Architectural and Structural plans of the building are essential. It will be helpful if detailed structural calculations including assumptions for the structural design are made available.

STEP 2:

If the Architectural plans and Structural plans are not available, the same can be prepared based on the site observations.

STEP 3:

Inspection of the Building – A detailed inspection of the building can reveal the following:

1. Any settlement in the foundations.
2. Cracks in columns, beams and slabs.
3. Concrete disintegration and exposed steel reinforcements photographs can be helpful.
4. **Slight tapping using hammer can reveal deterioration in concrete and wooden beams in Madras Terrace roofs.**
5. Corrosion in reinforcement.
6. Status of Balconies – sagging, deflection, cracks.
7. Status of Architectural features.
8. Cracks in walls indicating swelling in R.C.C members or defection of corrosion.
9. Leakages from terrace & Toilet blocks.

10. Leakages & dampness in walls resulting into cracks and corrosion.
11. Status of repairs & last repaired date.
12. What portion of the structure was repaired?
13. Who was the Agency?
14. How much was spent for repairs?
15. Are approved Building plans available?

STEP 4:

Preparation of Audit Report:

On the basis of inspection on building, an Audit Report is prepared.

STEP 5:

Tests Recommended:

It is important that various tests are carried out in the old buildings. This will give an idea about the extent of corrosion, distress and loss of strength in concrete & steel.

STEP 6:

Highlight the critical areas and how to go for repairs.

METHODOLOGY

1. Destructive Testing:

To verify the integrity of a component, it is always possible to cut or section through the components and examine the exposed surfaces. Components can be pulled or stressed and pressurized until failure to determine their properties of strength and toughness. Materials can be chemically treated to determine their composition. These are some forms of destructive testing. Unfortunately this approach of destructive testing renders the component useless for its intended use as against non-destructive testing which can be performed on the components and machines without affecting their service performance.

2. Non Destructive Testing:

Non-Destructive Testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms Non-destructive examination, Non-destructive inspection and Non-destructive evaluation are also commonly used to describe this technology, because NDT does not permanently alter the component being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. Common NDT methods the following:

1) Rebound Hammer Test.
2) Ultrasonic pulse Velocity (UPV) Tests.
3) Evaluation of the equivalent cube compressive strength of concrete by conducting tests on the core samples.

4) Carbonation Test.

5) Half-cell potential Test.

6) Evaluation of Chlorides and PH through concrete powder samples.

7) Profoscope Survey.

8) Tests on Reinforcing steel rebars.

Based on the yearly inspection of the Public structures, structural Audit may be carried out of such buildings that are over 30 years of age and also found to be structurally weak in the inspection and such other special cases where there is an urgent necessity to conduct the structural Audit irrespective of the age of the building. Thereafter, decision may be taken by the administrative agency concerned to strengthen the building to ensure safety or instead, **go for its demolition.**

Disposal of Buildings / Survey Report

(i) When a building has become unserviceable and beyond repairs, then it has to be disposed off or demolished by approving a survey report (i.e) the difference between book value and the probable amount expected to be realized by their disposal has to be arrived at and got approved by competent authority and building should be disposed off and then the actual loss is written off vide, powers under sale and dismantlement of buildings.

(ii) The Executive Engineers of territorial Divisions (Regular) are solely responsible to prepare / approve / forward to higher authorities, the survey reports relating to the buildings on the Register of Public Buildings / under their maintenance following the procedure contained in TNPWD PRACTICE.

CHAPTER XIII

Guidelines for Fire and Life safety Measures

The guidelines to be followed in Fire and Life safety in the buildings as per Part IV of NBC 2016 are furnished below.

1. General Exit Requirement:

a. Every building meant for human occupancy shall be provided with exits sufficient to permit safe egress of occupants, in case of fire or other emergency.

b. Provision of internal staircase, external staircase and corridor or passageway which have direct access to these staircases shall be maintained by occupants in case of emergencies and shall lead to the exterior of a building or to a street. Lifts and escalators shall not be considered as exits.

c. All buildings shall have a minimum of two staircases. The actual number of exits shall conform to the accepted standards on the basis of occupant load of building (Floor area in m2 required for a person), for different occupancies, width required per person and the maximum travel distance to be maintained in a building.

d. In general indicative terms, the occupant load will be 12.5 for residential occupancies, 15 for institutional, 4 for educational, 10 for office buildings, 0.65 to 1.80 for assembly, 3 for basement shopping area and 6 for upper floor shopping area in mercantile buildings. The travel distances to the nearest exits for all multistoried, special commercial, institutional and public buildings shall be of 30 m and for fully sprinklered building, the travel distances may be increased up to 45m

e. All the exits and exit passageways to exit discharge shall have a clear ceiling height of at least 2.40m . The height of exit door shall be at least 2.00m

f. Exit doorways shall not be less than 1 m in width but for assembly buildings it shall not be less than 2 m in width.

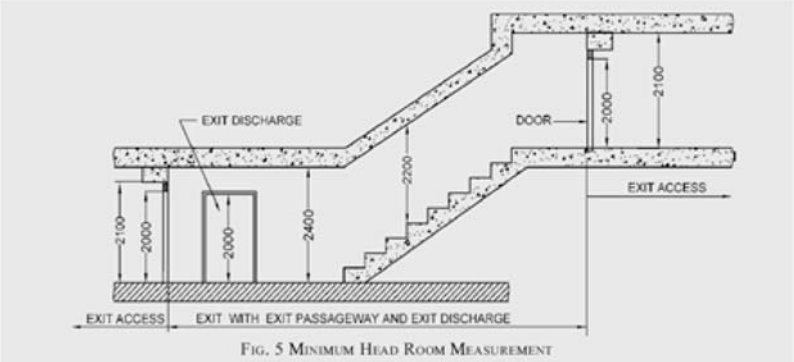


FIG. 5 MINIMUM HEAD ROOM MEASUREMENT

g. The minimum width of tread without nosing shall be 250 mm for internal staircase of residential buildings. This shall be 300 mm for assembly, hotels, educational, institutional, business and other buildings. The treads shall be constructed and maintained in a manner to prevent slipping. The maximum height of riser shall be

190 mm for residential buildings and 150 mm for other buildings and the number shall be limited to 15 per flight.

h. Internal staircase shall not be arranged round a lift shaft.

i. The internal staircases shall be constructed with non combustible materials and shall have a minimum fire resistant rating of 120minutes ; The external stairs shall be directly connecting all floors to the ground; it shall be continuous, free of obstructions and the entrance to the external stairs shall be separate and remote from the internal staircase.

j. The ramps shall comply requirements for staircases regarding enclosure dimension and capacity. The slope of the ramp shall not exceed 1 in 12 (8 percent)

k. Smoke Control: In building design compartmentation plays a vital role in limiting spread of fire. The building plan should ensure avoidance of spread of smoke to adjacent spaces. through leakage openings. All floors shall be compartmented with area of ach compartment being not more than 750 m2.

l. Pressurization is a method adopted for protecting the exits from ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies, etc, as applicable, to raise their pressures lightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the exits will be prevented. The pressurization of staircases and lift lobbies shall be adopted as per standards.

2. The fire detection and alarm systems include electro mechanical systems, such as air handling units, pressurisation systems, smoke management systems, creation of compartmentation through the release of fire barriers, hold up fire doors etc and monitoring of fire water storage tanks and pumps, pressures in hydrant and sprinkler systems etc. These systems should be provided as per standards.

3. The voice evacuation systems shall employ Tamil and English using pre recorded messages and integrate with fire alarm panels for alerting the zone of fire and surrounding zones / floors.

4. Fire Extinguishers/Fixed Fire Fighting Installations: All buildings depending upon the occupancy use and height shall be protected by fire extinguishers, wet riser, down-comer, automatic sprinkler installation, high/medium velocity water spray, foam, gaseous or dry powder system in accordance with the provisions of the NBC 2016

5. A satisfactory supply of water for the purpose of fire fighting shall always be available in the form of underground/ terrace level static storage tanks with capacities specified. The minimum water supply requirement is specified in Table.7 of NBC2016

6. Automatic sprinklers shall be installed in the false ceiling voids exceeding 800mm in height. The pressure in sprinkler system shall not exceed 12 bars.

7. Refuge area measuring to an extent of 15 sq. m shall be provided as a staging area and secured place for effecting rescue of occupants for all Multi-storey Building expecting residential occupancy where balcony is provided. To ensue life safety more stringent, refuge area shall also be –provided in the Commercial Special Building where is no sufficient near and side setback even though it is less than 24 m in height.

CHAPTER-XIV

PREFAB TECHONOLOGY – CONSTRUCTION METHODOLOGY

Basic concepts of the new technology in Pre-fab technology is presented explaining construction methodology etc., with a case study

Construction of 960 tenements adopting Prefab Technology at Murthingar Road, Vysarpadi, Chennai.by TAMIL NADU SLUM CLEARANCE BOARD **-(Case study)**

1. General:

The building is designed for G+7 floors using prefab technology. The units were designed in modular system which is very good for prefab technology, in term of repetition of moulds, achieving maximum productivity, simpler for identification of elements and erection, and stability of the structure.

The foundation work is designed with 450 & 600 mm diameter driven piles with pile cap and grade beams, which is all done in cast-in-situ method. The dowel bars for receiving the precast column will ensured in exact location using templates.

The superstructure consists of Precast Columns, Precast beams, Precast slabs, Precast Staircase with cast-in-situ structural topping concrete.

For walls, AAC blocks is been used for both external (150mm thick) and internal (100mm thick), and Solid Blocks of 150 mm thick were used for Lift and Staircase walls. All internal walls will be plastered with 12mm thick and external with 18mm thick. The ceiling will not be plastered as it has the smooth finish of the precast slab.

2. STRUCTURAL MEMBERS:

a. Precast Column

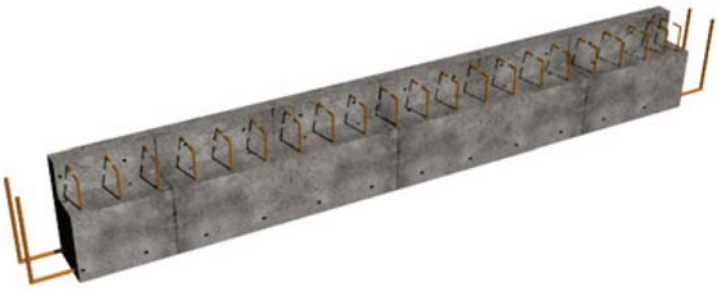
Precast columns of 230 x 450 / 600 mm is been designed in single and two tiers with corbels of 150 mm extended from the column to receive the precast beams. These corbels will have corrugated pipe for planting dowels during construction. There will be void in the columns for beam connection, which will be eventually filled with concrete during the structural topping concrete.

Single Tier Column

Two Tier Column

b) Precast Beams

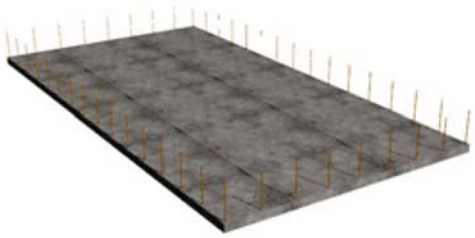
Precast beams of 230 x 450 mm is been designed as a partial precast beam, which means the top portion (150 mm thick) will be eventually casted along with the structural topping concrete. The precast beams will be having 30mm seating / bearing to receive the precast slabs.



Precast Beam (at Perimeter)

c) Precast Slabs

Precast slabs of 75 mm thick were sized to match the room dimension accordingly. These slabs will have provision for fan hooks and any other openings as required to run the services. The top surface of the slab will be roughened to have a good bonding with the structural topping concrete done over it eventually.



Precast Slab

d) Structural Topping Concrete

Structural topping concrete of 75 mm thick were poured over entire floor area (after the assembly of the column, beam and slabs) with nominal reinforcement as the design details. This structural topping concrete integrates all the precast members in the floor and provides the structure a monolithic effect of construction.

e) Precast Staircase

Precast staircase consists of three members, flight (2 nos.) and a mid landing slab. The precast flight has waist slab of 150 mm thick along with the steps. The mid landing slab has the integrated beam with it to receive the flights and the joints will be eventually casted after the erection of all these three elements.

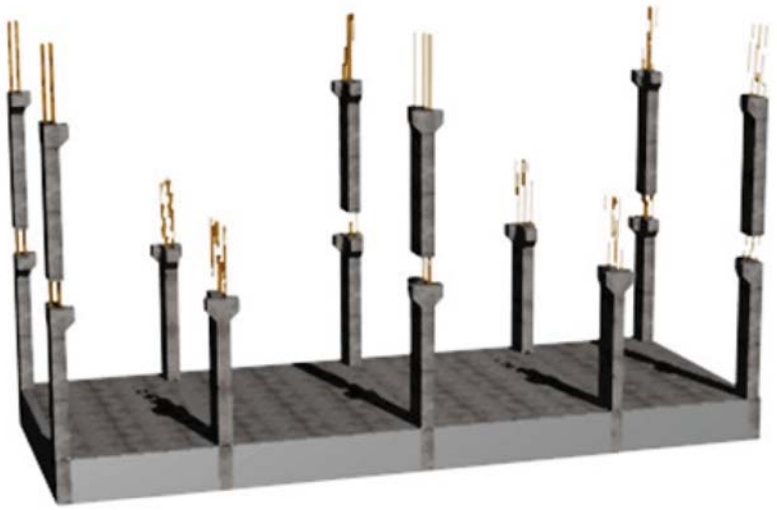
Precast Staircase

3. Assembly and Erection

a) Precast Column erection

On the ground floor, two tier columns will be used along the grid line 1, 3, 5, 7, 9, 11, 13 & 15 and single tier columns along grid line 2, 4,6,8,10,12 & 14 will be used. This arrangement is designed to get the staggered jointing details in column and as well as for easy installation of beams, which comes with the anchorage bars. The same arrangement is repeated on the terrace floor, where as the rest of the floor all columns will be two tiered.

These columns will be sitting on shim plates to create a gap about 25 mm and all the dowels provided from the foundation will receive the column. The column is checked for its position, verticality and alignment before it is been grouted. All the columns will be temporarily supported with the push pull props and will remain in position until the grout attains a minimum strength of 20 N/mm2.



Precast Column Assembling Sequence

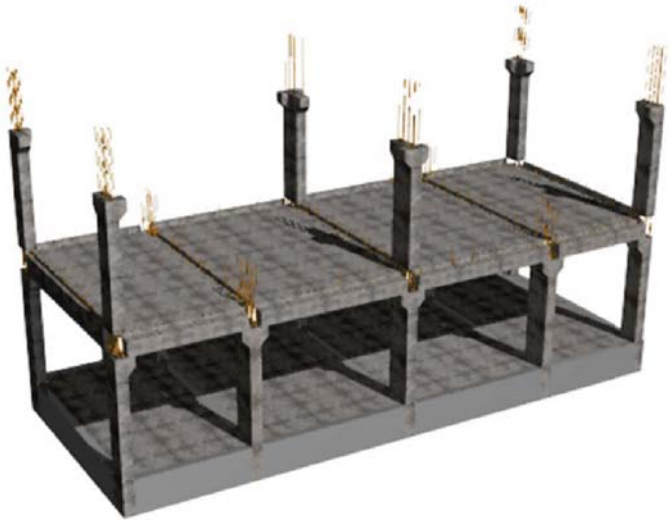
b) Precast Beam erection

Precast beams will also been provided with corrugated pipe at the bearing area, these corrugated pipe position will be matched with the same provided in the column corbel. The beam will be positioned at the required location and later a dowel bar will be placed connecting the corbel and will be grouted eventually.

Precast Beam Assembling Sequence

c) Precast Slab erection

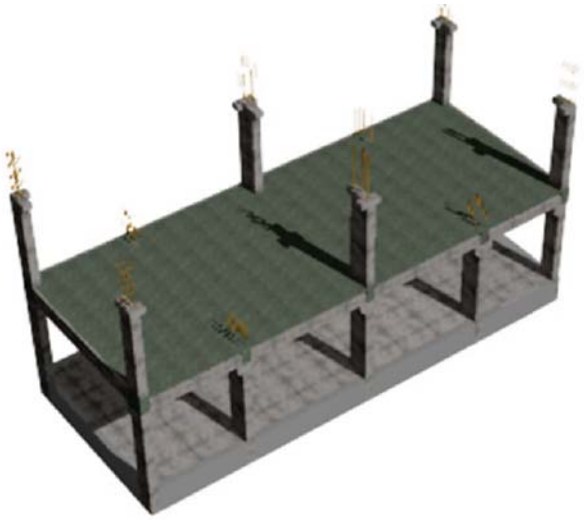
Precast slabs will be erected to the required position seating over the precast beams. Few props shall be provided underneath the slab as temporary support and for safety purpose, even though it is not required.



Precast Slab Assembling Sequence

d) Structural topping concrete

Structural topping concrete will be done after the reinforcement work is completed as per the details provided in the drawings for the beam and topping slab. This structural topping concrete fills all the voids, gaps happened during erection process as it is designed with tolerances. Also these topping concrete integrates all the precast members in the floor and makes the structure as monolithic.



Structural topping concrete

e) Precast Staircase

The mid landing slab is been erected with props as temporary support and over which the first and second flight is been erected. All the joints reinforcement will be done as the detailed drawings provided and casted eventually. These staircases shall be protected as it is a finished product.

Precast Staircase assembling

4. Safety in Installation of Precast Element

Safety Measure:

1) Generally the crane must be of sufficient capacity to hoist any precast element.
2) All lifting radius, lifting load, and boom length have to be considered before engaging a crane.
3) Competent operator has to be assigned to do the lifting.
4) All lifting gears capacities must be carefully chosen to lifting the precast elements
5) All lifting gears must be checked on regular basis for damages.
6) All the signal man and riggers shall be competent enough to do the erection operation.
7) Walkie talkie shall be used for communication between the crane operator and the signal man
8) No one should be allowed to stand under the suspended load.
9) The erection area to be barricaded properly.
10) Tool box talks shall happen every day before the start of the work.

CHAPTER-XV

GUIDE LINES IN CONSTRUCTION FOR FIELD ENGINEERS

FOUNDATION / MAT CONCRETE

- Mark the top level of the matt concrete on the excavated wall surface.
- Ensure the size of the 40mm metal and its shape. Avoid using flaky metals.
- Control the water cement ratio of the concrete to avoid dry mix.
- Tamp the concrete with specified cast Iron rammer and finish the top surface and edges truly.
- Ensure effective curing.
- Transfer the centre line mark on the top surface of the mat concrete.

PREPARATION OF MORTAR

Mortar it is a paste to bind different or same material to construct a structure to the required shape.

- For preparing mortar a platform should be made in the required places with necessary cover overhead.
- Necessary mortar pit should be made for mixing mortar with water.
- The mortar should be prepared in dry condition and it should be mixed with water in the mortar pit whenever it is required to avoid initial setting time before using.
- The sand should be free from organic matter, clay lumps and pebbles.

R.R. MASONRY

Ensure that the minimum size of the stone is 200mm x 200mm. Don't use weathered stones.

- Use bond stones for full width of the layer at every 2m intervals. Mark the bond stones with paint for verification. For 60cm course, if required length of the bond stone is not available, overlapping with a minimum lap of 15cm or scissor bond may be provided.
- All the corner stones should be dressed for one inch on either faces to ensure the verticality during construction.
- Vertical joint should be avoided.
- Ensure proper bondage using bond stone at junctions and corners.
- Ensure the use of mortar mix as per the specifications and allowable-bulkage of sand as per the field test.

- Mortar should be thoroughly mixed with required consistency in wooden mortar box and packed inside the R.R. masonry.
- Verification of voids by pouring water on the masonry at regular intervals should be done.
- Ensure the inside the packing of the RR masonry using angular stones and sides of the masonry packed then and there.
- Ensure staggered use of stones for proper interlocking.
- Transfer the centre line to every layer of the masonry to avoid eccentricity.
- Avid using extra mortar over the top layer of the masonry for levelling the surface.
- Refilling the sides of the foundation should be done with excavated earth and not with bouldlers. Proper consolidation should be done.

PLINTH BEAM

Ensure proper alignment of centering with planks and avoid using coconut planks.

- Check the reinforcement as per design and ensure proper cover to the reinforcement bars by placing cement mortar cover blocks.
- Place the concrete as per specification with proper compaction.
- Provide gauges at regular intervals for centering to prevent bleeding and weeping of cement slurry from concrete by proper filling of the gaps.

BRICK MASONRY

- Use header and stretcher bond with proper closers to avoid vertical joints.
- Brick should be soaked using double drum system before it is laid.
- Maintain uniform thickness of mortar.
- The top surface of every layer should be truly leveled.
- All joints should be racked to receive plastering.
- Unburnt, half burnt and brick bats should be avoided in construction.
- Holes in the masonry should be filled with concrete only and proper care should be taken for curing the filled concrete.

BASEMENT FILLING

Filling the basement with excavated earth should be done in layers of 15 cm thick with proper consolidation.

- Before filling the basement the floor and sides of the inner rooms should be applied with anti-termite treatment.
- Ensure proper consolidation of basement filling by flooding with water.
- After sand filling for flooring concrete, holes should be made at every 1m intervals for applying anti-termite treatment.

FLOORING

Zero level should be maintained for flooring concrete. The top surface should be let rough to receive floor finish.

- Uniform thickness of flooring concrete should be maintained by using gauge at regular intervals.
- The ceramic / Vitrified / Granite flooring should be of specified thickness and the mortar should be mixed properly with water. Dry mortar should be avoided.

FORM WORKS

- Cantilever centering should be avoided for sunshades.
- Surface of the centering sheets should be plain without undulations.
- The runner used for centering should be of required size and setion.
- Avoid using wooden planks in between centering sheets instead of adjustable MS sheets.
- The joints of the centering sheets should be lead proof.
- The top surface of the centering should be checked for true level.
- Casuarina posts of proper diameter at required intervals should be used for strutting.
- No bricks should be used underneath the props.
- Cross bracings should be provided adequately.
- In special cases, where head room is high, acro spans and jacks may be used.
- In case of columns centering, verticality should be ensured with side support on all sides.
- Round cover blocks should be used for columns.
- For beams, gauges should be provided at regular intervals and the joints should be made leak proof.

REINFORCEMENT

Chair rod should be used wherever necessary and should not rest directly over the centering.

- Proper cover should be maintained using cover blocks at regular intervals.
- In case of stirrups for columns and beams, the free ends should be bent towards inside.
- The free end of the stirrups should be placed staggered to have more stability.
- The column rod lapping should be done in a staggered manner.

CHECK LIST (REINFORCEMENTS)

1. Whether the reinforcement were tested for strength.
2. Whether reinforcements were verified with drawing.
3. Necessary cover blocks were provided or not.
4. Laps were provided and details of the number of laps.
5. Whether the laps were staggered.
6. Whether the lap length were adequate.
7. All the rods were tied properly with binding wire as like the scissors type tying method.
8. Whether the rods were bend as per details in the Column beam junction.
9. Proper chair rods should be provided so as to keep the top layer of rods in position.
10. Whether the cradle hooks and fan books were provided at proper locations.
11. Necessary cranks were provided or not.
12. If positioning of rods is difficult for easy flow of concrete necessary bundling mthod should be adopted.
13. For future expansion necessary dowel rods were provided or not.
14. Details measurements of the reinforcements should be taken.
15. Necessary extra rods were provided in the opening and irregular portion, etc.
16. Necessary dowel rods provided for drops and lintels, etc.
17. Necessary spacer rods were provided for walls, drop portion, etc.
18. If at any place if the spacing of reinforcements looks complex and difficult, the issue should be discussed with the Structural Engineer / Verified with the detailing books.

19. Dowel rods should be properly protected from any kind of accident.
20. Whether the requirements for Earthquake resistance were made.
21. Whether proper ties / rings were provided in the Column beam junction.
22. Whether movement benches were provided to avoid disturbance of the steel rods.
23. Whether proper hooks were provided for mild steel rods.
24. Whether the rod is free from oil or grease.
25. In the Column beam junction if it is not possible to insert the steel rings, the rod should be made to 'U' shape and it should be tied properly.
26. The Excess length rod should not expose over concrete, instead it should be cut by leaving proper cover.
27. The development length of the rod provided for future expansions should be covered with dense material to avoid seepage of water and otherwise it will affect the stability of the structure.
28. Placing of rods should be done only after proper levelling for roof.
29. The extra rods provided should not cross the expansion joint.
30. All the rods should be well placed in their position.

CONCRETING

- Check the measuring box for dimension.
- The coarse aggregate should be angular and roughty cubical.
- The coarse aggregate should be stacked in clean platform and it should be made clean, hard non-porous, free from clay, organic matter, etc.
- The slump cone test should be done to ensure the workability of the concrete.
- Before placing the concrete the surface should be thoroughly cleaned and wetted.
- Mechanical vibrator of specified diameter should be used for compacting the concrete.
- Avoid over vibration.
- The beam members and heavy concretes should be laid in layers.
- Concrete cubes should be prepared for all RCC works as per the quality plan.
- To maintain the consistency of the concrete laid, using hoist, plasticizer may be used.

- Curing of concrete should be done in adherence with the codal rules.
- Do not stack any materials over the green concrete.
- Gunny bag curing may be done for green concrete to avoid dehydration.

CHECKLIST FOR PLACING OF CONCRETE

1. Plan and design formwork and reinforcement layout to suit the speed of placement and equipment proposed to be used.
2. Plan sequence of each layer and width of the layer avoiding cold joints (Massive pour).
3. Concrete placed at or as near as possible to its final position without loss of workability or causing segregation.
4. Avoidance of heaping of concrete.
5. Concrete placed in layers without occurrence of cold joints.
6. Concrete dumped vertically without hitting any obstruction (Form work, reinforcement, etc.,)
7. Vertical dumping (free fall) maximum 1.0m of height.
8. Adequate drop chutes with rounded cross section available at site.
9. Slopes of inclined chutes not less than 1 vertical to 2.5 horizontal.
10. Chutes or conveyor belts mobile enough for easy placement.
11. Availability of tremie pie or funnel for large drops.
12. Placing in layers of uniform thickness between 150 to 300 mm, however not more than 500 mm in any case.
13. Placing speed matches compaction speed.
14. Placing of concrete in walls, columns and deep members at a rate greater than 2 m per hour (Improved finish).
15. Avoidance of delays, interruption and stoppages.
16. Placement of upper layer only after lower layer is well compacted.
17. Placement of upper layer before the lower layer commences to harden.
18. Flow of concrete or concrete placing to commence from corner and ends.
19. Concrete in slab placed against hardened concrete of the previously case concrete slab.
20. First layer placed or hardened concrete of previous pour or on rock surface not more than 500 mm.
21. Level of top layer maintained uniformly during placement.

22. Concrete of top layer slightly drier in consistency.

23. Prevention of bleeding by attending to deficiencies like less fineness or high slump.

24. Availability of protective covers for freshly placed concrete in case of unforeseen stoppage.

25. Clear visibility of deep areas for inspection during placing (Provisions of windows, lighting, etc.,)

26. Width of working platform to be adequate.

27. Workers with muddy boots or bare foot kept out of freshly placed concrete.

28. Engineers / supervisors / workers available, to continuously inspect forms, bracings, props and other supports.

29. Availability of temperature monitoring devices for concrete temperature measurement (If necessary or specified).

30. In hot weather all placing equipment used to be white or light coloured and covered with wet hessian.

31. Suitable ambient temperatures during the placing.

32. Whether tarpaulin or plastic covers should be made ready before starting concrete to cover during the interruption by rain.

CURING

- Any concrete hydration process is an important process (hardening of concrete).
- It will happen in a cool atmosphere hence the concrete should be wetted properly.
- If a concrete is laid it is like a just born child. A just born child is not properly fed, it will die so the child should be fed properly to gain strength and grow with great stamina.
- Like that if a concrete is not properly cured in the initial stage it will lead to lose in its strength and life of the structure will get affected.

WEATHERING COURSE

The name itself defines the protection of weathering action to the structure. Hence, the hair in the human body can be compared to this. If the weathering course is not properly laid, the water will penetrate into the concrete which consequently will weaken the roof. Hence, the building without proper weathering course will affect the roof of the structure.

The roof slab should be cleaned from curing pond mortar, dust and loose materials and thoroughly wetted before placing the weathering course.

The brick jelly to be used should be of specified size and free from dust. The effect of lime should be tested before using.

PRESSED TILES

The tiles laid over the weathering course can be matched with the hat on the head. To avoid direct impact, the hat is put on the head. Likewise, the tiles are laid over the weathering course.

- Uniform flat surface of the pressed tiles should be ensured.
- Pressed tiles should be soaked in water for 24 hours before laying.
- The thickness of the joint should be uniform and kept to a maximum of ½ inch.
- The joint of the tiles should be packed individually instead of spreading the mortar all over the surface.
- Water should be stacked over the pressed tiles after wetting to ensure the water tightness.
- The mortar used for packing the joint of the tiles should be mixed with water proofing admixtures or crude oil. Undulations shall be checked and aligned during execution.
- All the edge tiles near the parapet wall should butt into parapet wall.
- Flashing tiles should be provided with curved borders at the top.
- Proper bell mouth should be provided for rain water pipes and free flow of water.
- The rain water pipes should be provided to full width of the parapetwall, for free flow of water.
- After laying pressed tiles, do not mix mortar / concrete over the tiles.

PLASTERING

- Before plastering, ensure that the entire room is fit for plastering (i.e) fixing of joineries concealing electrical lines, etc.
- All concrete surfaces should be hacked at closed intervals.
- The brick wall should be thoroughly cleaned and wetter before plastering.
- To maintain uniform thickness of plastering, buttons at regular intervals may be provided.

- The inner wall plastering should be finishing smoothly, while the outer surface and ceiling should be finished with medium roughness.
- All corners of the walls and edges should be finished with rich mortar.
- A bend may be fixed in position at floor level for rain water. Ensure proper packing of soil and waste water pipe holes in wall before plastering.
- Avoid chipping of plastered surface.
- The top surface of the parapet wall should be finished with inward slope for main water.

FLOOR FINISHING

- The floor should be made free from dust, loose particulars and dead mortars, before laying the floor finish.
- Required level of the floor finish should be ensured by providing buttons.
- In bathrooms and toilet, the floor tiles should be butt into the wall and the wall dadoing tiles should rest over the floor tiles.

ELECTRICAL WORKS

- The detailed electrical layout should be prepared and got approved before execution.
- Wall cutting for concealing the electrical conduit pipes should be done perpendicularly and conduit pipes should be ties with nail and binding wire before plastering.
- The gaps in wall after cutting and placing of conduit pipes should be filled with mortar mixed with chips. Care should be taken to cure the filled up portions.
- The PVC conduit pipes used for electrical wiring should be of heavy duty with ISI mark.
- The metal switch boxes to be used should be of 16 gauge thickness. There should not be any hole at the rear side of the switch box, to avoid looping in wiring.
- Care should be taken while fixing the switch box that all the inner sides are properly packed with mortar without any gap inside. Before fixing metal boxes ensure that all the boxes are painted with primer coat.
- The bottom of the switch boxes should be fixed at 1.35 m above the floor level. For convenient plugs / TV plugs, AC points the top of the box should be taken that switch boxes are fixed in correct position.
- While laying roof concrete, broken PVC conduit pipes should be replaced then and there and the presence of the electricians during concreting is compulsory to attend the above works.

- Care should be taken while positioning of fan hooks / boxes, cradle hooks. The fan hooks should be fixed at the centre of room deducting the loft area if any, with a clean sweep of 1.20 m and for cradle hook it should be fixed minimum 90 cms away from the walls.
- Periodical check should be made to ensure that the approved cable has been used for entire length of each point, to avoid looping with sub standard cables.
- Three pin ceiling rose should be used to ensure that all the points should have 3 wires for phase, neutral and earth.
- Looping of cables should be strictly avoided and the run off wire for each box should be taken from the nearest junction box. For 15 amps power plug / AC plug, run off should be taken separately from the main board / ELCB.
- Before closing the switch box with hylem sheet all the dead mortar should be thoroughly cleaned and if required one more primer coat should be applied.
- Utmost care should be taken for constructing earthing station as per the standards.
- U.G. cables should be laid at a minimum depth of 75 cm from ground level with required sand filling and brick bats. Joints in U.G. cable at any point should not be allowed.
- After completion, all the ELCB should be individually tested for correct functioning.

PLUMBING

- The diameter of the suction, delivery and number of branch pipes from main lines shuld be designed well in advance before starting the work. A layout of plumbing line should also be prepared and got approved.
- All the horizontal lines should be taken along the parapet should be vertical. In any case if horizontal lines could not be avoided, it should be concealed. Adequate clamps should be provided at closer intervals.
- Before fixing of vertical ad horizontal pipe lines, the verticality and straightness of the pipes should be ensured by making vertical and horizontal marking lines on the plastered surface.
- Making holes in the walls for taking pipe lines inside should be done from outside and an approximate circular mark may be made at the inner walls using chisels to avoid excessive damage in plastered wall and spreading of plastering cracks.
- For bath rooms the horizontal line should be taken at 45 cm above floor level and the tap should be fixed at 75 cm from floor level. The shower

point should be fixed at 2.10 m above floor level. The pipe line at the toiler should be taken at 45 cm above floor level and tap fixed at same level.

- Inter connection pipes among PVC tanks should be provided at the top of the tank. The top surface of the OHT slab should be smoothly finished with required outward slope so that the overflow water will freely flow without stagnating on the slab. The overrfow pipes for all the PVC tanks may be inter connected and disposed in rain water pipes.

DAMPNESS IN WC AND BATH WALL – INSTRUCTIONS

In most of the places the WC and Bathroom portion are found with dampness. After a long study it is observed because of crude method being adopted for fixing of pipe line and lack of supervision for this works, lead to affect the stability of the structure as well as aesthetic looks of the building. Hence, all the Executive Engineer's are requested to advice the field staff to follow the procedure as follows to avoid such defect in the building.

1. CAUSE NO.1

Holes are being made in the wall by manually for fixing of WC and Bath pipe line after sunken portion is plastered for water tight, by using water proof compound. Mostly unskilled labour is being engaged to make the hole in the wall and he is breaking the wall in haphazardly manner, resulting in surrounding portion of the hole are get disturbed damaged and mile and cracks are appeared.

REMEDY

Hole to be made in the wall before plastering the sunken portion water tightness. For making hole skilled labour to be engaged. The pipe line in the hole to be fixed in such way to suit proper jointing with S or P trap or Nahini trap. The hold should be packed with Bricks bats with rich mortar.

For packing of holes also skilled mason to be engaged for proper plugging of holes. After finishing the above works, the sunken portion in WC and Bath to be plastered for water tight using water proof compound and proper curing to be done.

2. CAUSE NO.2

Improper jointing of pipe line with S or P or Nahini trap and lack of curing for jonts.

REMEDY

More care should be taken in jointing the pipe line with S or P or Nahini trap properly. For jointing work skilled mason to be engaged for proper joints, instead of unskilled labout being engaged usually. Proper curing to be done joints and joints should be tested for leakage before filling the sunken portion. While filling the sunken portion. While filling the sunken portion, proper care should be taken to avoid disturbing the joints already provided with P or S or Nahini trap.

3. CAUSE NO.3

Improper jointing of wall tiles and floor titles at the junction of the wall and floor.

REMEDY

Usually in Bath and WC the wall tiles are fixed first and then floor tiles are laid. This is not correct method, this will lead to improper jointing of wall tiles with floor tiles at the junction of wall and floor, resulting in leakage through the above joints . Hence, to avoid such defects, the floor tiles to be laid first, and then the wall tiles to be fixed.

SANITARY WORKS

In a building, the bath & WC occupies a small space. But its role is significant. We can compare this part with kidney in a human body. If the Kidney is failed, it is more dangerous to the life. Similarly, if any defect occurs in the sanitary work of a building, first the occupant cannot live in the building. Subsequently, it will spread to the neighbours.

- A layout for sanitary lines with chambers, sewer lines with required size slope should be prepared before execution.
- The sunken portion of WC should be made damp proof by plastering the inner portion with rich mortar mixed with water proofing compound and corners should be finished curved.
- After fixing the I.W.C. and E.W.C., the water tightness of the joints should be checked by providing an upward bend and stacking water inside closet.
- In case the position of PVC Nahini trap comes below the finished floor level of bath room, a PVCV connection pipe of same diameter should be fixed upto the floor level and a gratings may be fixed.
- Tar coating should be applied in the sunken portion after plastering and before filling the sunken portion.
- All the vertical soil lines should be directly connected to a chamber abutting the building without any bend or connecting pipes.
- Proper care should be taken for giving smooth benching and channeling inside the chambers.

FIXING OF NAHINI TRAP IN BATH ROOMS

In some places the bath room wall portion are found with dampness. It is mainly due to improper fixing of Nahini trap.

While fixing Nahini trap, the gap between top of Nahini trap and top of finished floor level of bath (Indicated in the figure enclosed) is finished without inserting a piece of PVC pipe. In general, this is being finished with mortar by making ground floor sump.

This may lead to seepage through sides of floor sump finished with mortar. Hence, this should be avoided and the Nahini trap to be fixed as per sketch enclosed to avoid dampness in wall.

WASTE WATER AND RAIN WATER PIPES.

- The position of the rain water pipe should be designed so that it will not affect the aesthetic view of the building. For every 450 sq.ft., one number of rain water down fall pipe may be provided.
- All the waste water and rain water pipes should be directly led into a gully trap without bends or connection pipes before disposing it to open drains or UGD.

JOINERY WORKS

- If teak wood is to be used for door frame and shutters, it should be free from knots and the allowable white may be 10% of the total area.
- Seasoned teak wood should be used to avoid cracks in future.
- Before fixing the door frames and shutters one coat of primer should be applied. If it is to be varnished only the inner surface of door frame butting the wall should be applied with anti-termite treatment.
- Verticality should be maintained while fixing doors, windows and also PVC door frames.
- For steel windows, stay rods should be fixed so that is doesn't protrude out of the window jams at any position.

JOINERY WORKS

- For concrete door frames, the threshold plate provided should be embedded in flooring. At any cost the bottom tie rod should not be cut and removed.
- While fixing Glass panels in Steel window frames, putty paste should be applied all around the gap instead of applying at specific points.
- If RCC jally is used, louvered type jally should be used and the shape of the holes in jally must be uniform.

PAINTING AND COLOUR WASHING

We can compare the painting work of the building with the dressing a person. becaue this only gives an elegant appearance for both human and building. All the good quality of the construction can be exposed only in painting work. Choosing the apt colour

is imperative to the elevation of a building.

PAINTING AND COLOUR WASHING

- The color scheme should be got approved before execution.
- If cement paid is to be used for inner and outer wall, mixing should be uniform with specific proportion of water. The quantity of cement paid mixed with water should be used within 3 hours, to avoid setting.
- The walls should be properly cleaned from dead mortar and should be wetted before and after application of cement paid for proper setting.
- All the steel windows, wooden door and wooden shutters should be cleaned with sand paper before applying enamel paint. Thinner should not be mixed with enamel paint as the paint is already mixed.
- Application of cement paint primer on walls should be done both in vertical and horizontal directions for proper coverage and this is called one coat.
- During colour wash and ceiling painting, water may be stacked on the floors of rooms or gunny bags may be spread over the floor to prevent the spilling of cement paint directly on the finished floor.

SAFETY MEASURES DURING CONSTRUCTIONS.

Like a human life's Past, Present and Future, safety of a building can be categorized in three stages viz., Preconstruction, During Construction and Post-construction. Prevention is better than cure. Hence, utmost care should be taken in safety measure.

- No child labourers should be allowed.
- Helmets, Gloves and Gum boots should be provided to the labours by the contractor.
- Insurance should be taken by the contractor for all his workers / employees.
- To avoid fire accidents, thatched roofs should be avoided for labour shed.
- Shallow ditches should be provided around the scheme, stacked with water to avoid poisonous insects entering into the scheme.
- A full fledged first aid box with all specified medicines should be kept at site.
- The awareness of first aid treatment methods may be created among the employees by conducting training at site.
- All the free ends and excavated portions should be barricaded with red tapes and with danger marks.
- All the temporary electrical lines should be taken above the Ground level with proper insulation at an unreachable height.

CHAPTER-XVI

MISCELLANEOUS TECHNICAL POINTS

16. 1 Concrete grades for Coastal & Non-Coastal areas –Instructions

(AS per Technical Circular No.AEE T10/3356 /2017, dated 27.04.2017)

Table 5 of IS 456-2000 (page 20) specifies minimum grade of concrete for various exposure condition and is reproduced as follows:-

Sl. No	Exposure condition	For Reinforced Concrete
		Minimum Grade of Concrete
1	Mild	M20
2	Moderate	M25
3	Severe	M30
4	Very severe	M35
5	Extreme	M40

Clause 8.2.2 and Table 3 of IS 456:2000 classify, Environmental Exposure Condition as Five levels of Severity viz., MILD, MODERATE, SEVERE, VERY SEVERE and EXTREME condition of Environment to which the concrete will be exposed during its working life and is reproduced as below:-

SI.No (1)	Environment (2)	Exposure conditions (3)
i)	Mild	Concrete surfaces protected against weather or aggressive condition, except those situated in coastal area
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet. Concrete exposed to condensation and rain. Concrete continuously under water. Concrete in contact or buried under non-aggressive soil / ground water. Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation Concrete completely immersed in sea water. Concrete exposed to coastal environment.
iv)	Very severe	Concrete surfaces exposed to sea water spray, correction fumes or severe freezing condition whilst wet. Concrete in contact with or buried under aggressive sub-oil / ground water.
v)	Extreme	Surface of members in tidal zone. Members in direct contact with liquid / solid aggressive chemicals.

As presented in the above Table , the Indian Code IS 456-2000 for plain and reinforced cement concrete specifies five exposure classifications namely, mild, moderate, severe, very severe and extreme, which seem to be arbitrary and prescriptive in nature regarding durability requirements. IS 456-2000 does not specify the limit of distance from the seawater front to be treated as coast.

The extent of saline zone would depend on local condition of the humidity and wind characteristic. It is difficult to give a clear-cut specification as to the distance from the sea coast up to which the saline atmosphere would have effect on the RC concrete.

In the circumstances explained above, considering Safety , Sustainability as well as economy and after having detailed discussions with the experts , the various grades Concrete to be adopted normally in coastal and non coastal areas (ie.,M20, M25, M30) with respect to the Distance from sea water front is suggested as below in order to improve the durability of Reinforced Cement Concrete in accordance with the IS:456-2000 BIS code.

Grade of concrete to be adopted for Reinforced Concrete under various exposure condition :-

Sl. No	Exposure condition	Grade of Concrete	Distance from Sea Water Front
1	Mild	M20	Beyond 24 Km
2	Moderate	M25	Beyond 10Km and up to 24 km
3	Severe	M30	Up to 10 km

16. 2 Condition Assessment of Concrete in the RC Structural Elements of the Working Women's Hostel Building of the SWD at Adyar, Chennai - CASE STUDY

1.0 INTRODUCTION

M/s Greater Chennai Corporation (GCC), Chennai intended to assess the condition of concrete in the Reinforced Concrete (RC) Structural Elements of the Working Women's Hostel Building of the Social Welfare Department (SWD) at Adyar, Chennai. A consultancy project proposal on "Condition Assessment of Concrete in the RC Structural Elements of the Working Women's Hostel Building of the SWD at Adyar, Chennai" was submitted by M/s Hitech Concrete Solutions Chennai Private Limited, Chennai. M/s GCC, Chennai confirmed the scope of work and entrusted the work to M/s Hitech Concrete Solutions Chennai Private Limited, Chennai. The site investigation to assess the condition of concrete in the RC Structural Elements of the Working Women's Hostel Building of SWD at Adyar was carried out by M/s Hitech Concrete Solutions Chennai Private Limited, Chennai on 19-04-2018. This report outlines the details of the site investigation carried out to assess the quality of concrete and the Rehabilitation Methodology to be adopted for the distressed structural elements.

2.0 SCOPE AND OBJECTIVE OF THE WORK

The following is the scope of work:

- Core test to evaluate the equivalent cube compressive strength of the concrete -- 6 Nos.
- Carbonation test on 6 core samples
- Half-cell Potential Test – 7 locations
- Evaluation of chlorides & pH through concrete powder samples – 6 locations

3.0 DESCRIPTION OF THE STRUCTURE

The structure is a Reinforced Concrete framed structure with Ground + 2 floors. **Photo 1** shows a view of the Working Women's Hostel Building of the SWD at Adyar. **Fig. 1** gives the typical lay out of the Women's Hostel Building at Adyar.

Photo 1 A View of the Women's Hostel Building at Adyar, Chennai

4.0 VISUAL OBSERVATIONS

The following are the distresses noticed during the visual inspection of the Working Women's Hostel Building.

- Spalling of concrete and exposure of rebars was noticed in the RC roof slab in the second floor near the staircase **(Photo 2).**
- Spalling of concrete and exposure of rebars was noticed in the RC roof slab & RC Beams in one of the rooms in the second floor of the building **(Photo 3).**
- Minor spalling of concrete and exposure of rebars was noticed in the RC roof slab of one of the rooms in the second floor of the building **(Photo 4).**
- Cracks were noticed in the parent RC slab after removal of weathering course in the terrace.
- Minor cracks were noticed in a RC Column of staircase in the ground floor.
- It was observed that the distress was mostly confined to the second floor roof slab probably due to damaged weathering course and consequent water seepage from the terrace of the building. At the time of the inspection, the damaged weathering course is being removed **(Photo 5)** and action has been initiated for the waterproofing.

Photo 2 A view of the spalling of concrete & exposure of rebars noticed in the RC Roof slab near staircase at second floor

Photo 3 A view of the spalling of concrete & exposure of rebars noticed in the RC Roof slab & RC Beam in one of the rooms at second floor

Photo 4 A view of the minor spalling of concrete & exposure of rebars noticed in the RC Roof slab in one of the rooms at second floor

Photo 5 A view of the weathring course being removed

5.0 INVESTIGATION AT SITE

5.1 Choice of Test Method

The following test methods were employed to assess the quality of concrete in the RC Structural Elements of the Working Women's Hostel Building at Adyar:

1. Core Drilling Test
2. Carbonation Test
3. Half Cell Potential test
4. Determination of chlorides and pH

5.2 Core Sampling of Concrete

Concrete core samples were extracted from the selected RC structural elements in the various floors **(Photo 6).** The diameter of the core samples that were extracted was 69 mm. A Profometer was used to identify the locations of the reinforcement in the RC structural elements that were chosen for the core test**.** Concrete core samples were drilled from 2 RC columns, 2 RC beams and 2 locations in the RC slab of the various floors. In all, 6 concrete core samples were extracted from the RC structural elements of the Working Women's Hostel Building.

Photo 6 A view of the core drilling test in progress in a RC beam at the Ground floor

Immediately after the extraction of the concrete core samples, they were tested to check for carbonation. The cylindrical concrete core samples were sprayed with 1% solution of phenolphthalein in alcohol indicator. If the sprayed portion results in colourless surface, it indicates the extent of carbonation **(Photo 7). Table 1** gives the results of test for presence of carbonation in the concrete core samples.

Photo 7 A view of the carbonation test in the extracted core sample

The ends of the concrete core samples were dressed by cutting the edges suitably in the laboratory and the cylindrical test specimens of size 69 mm diameter and of sufficient length were cut from the core samples for testing them to obtain the compressive strength of concrete. UPV tests were conducted on the 6 core samples. The cylindrical test specimens were then capped with a sulphur compound and tested in a 1000 kN Universal testing machine to obtain their compressive strength.

The equivalent cube compressive strength was calculated after applying the correction factor for l/d ratio, cylinder to cube conversion factor of 1.25, and an additional factor of 1.08, which is suggested by SP-24 to account for the size effect in case cores of diameter smaller than 95 mm are extracted. It should be noted that SP-24 was used in conjunction with IS 456:1978 and is not in use today because of the change in the concrete code to the new IS 456:2000. Nevertheless, the factor of 1.08 is legitimate from the point of view of accounting for the size effect. The equivalent cube compressive strength of concrete core samples is given in **Table 1**.

Table 1 Detailed Results of the Core and Carbonation Test

Sl. No.	Member Identification	Dia. of the core sample in mm	Length of the core sample in mm	UPV in km/s	Carbonation depth in mm	Equivalent cube compressive strength (N/mm^2)
1	RC Column – Ground Floor – Near Staircase	69	85	3.96	70	25.9
3	RC beam – Ground Floor	69	138	3.91	70 mm on one face and 80 mm on the other face of the core	7.3
2	RC Column – 1st Floor – Near Staircase	69	138	3.87	240 mm for the entire depth of the core	8.6
5	RC slab – 1st Floor Roof Slab	69	105	3.74	70mm	24.0
4	RC beam – 2nd Floor	69	138	3.81	80 mm on both the faces of the core	10.1
6	RC slab – 2nd Floor Roof Slab	69	100	3.83	20 mm	14.8

5.3 Half-cell Potential Test

This method covers the estimation of electrical half cell potential of reinforcing steel in concrete for the purpose of determining the corrosion activity of the reinforcing steel. A copper-copper sulphate (Cu-CuSo4) electrode (reference electrode) was used to measure the half cell potential. It consists of a rigid tube that is non-reactive with copper or copper sulphate, a porous sponge placed at the conduct end that remains wet by capillary reaction and a copper rod that is immersed within the tube in a saturated solution of copper sulphate. The solution was prepared with reagent grade copper sulphate crystals dissolved in distilled water. The solution was considered super saturated when an excess of crystal (undissolved) lies at the bottom of the solution.

Half-cell potentiometer works on the principle of measuring voltage in the circuit of reinforcement and cover concrete using Copper Sulphate Half-Cell. This method essentially consists of measurement of the absolute potential of the concrete with reference to the reference electrode. The reference guidelines for the probability of corrosion ASTM C-876 **[1]** is presented in the **Table 2.**

Table 2 Reference guidelines for probability of corrosion (ASTM C-876)

Sl. No	Measured Potential Difference	Probability for Corrosion
1	More negative than (-) 350 mV	There is a greater than 90 % probability that reinforcing steel corrosion is occurring in that area at the time of measurement.
2	Between (-) 200 mV to (-) 350 mV	Corrosion activity of the reinforcing steel in the area is uncertain.
3	More positive than (-) 200 mV	Greater than 90 % probability that no reinforcing steel corrosion is occurring in that area at the time of measurement.

The half-cell potential test was conducted in 7 selected RC structural elements of the various floors of the Hostel Building. It is a pre-requisite that the structural elements that are to be subjected to half cell measurements have to be fully saturated during the measurements and hence the structural elements were pre-wetted before taking the readings **(Photo 8)**. Even though this method has limitations, it is still widely used and is being recognized to be a useful tool for assessing the probability of corrosion. **Table 3** gives the results of the half-cell potentials.

Photo 8 Half-cell potential test in progress in a RC column of the Ground floor

Table 3 Half Cell Potential Test Results

Sl. No	Location	Half Cell Potential Readings in mV
Ground Floor		
1	RC column - Room No 1	-259, -286, -310, -285, -290, -315, -318, -340, -219, -262
2	RC beam - Room No 1 - Ground Floor	-276, -282, -225, -296, -275, -252, -260, -284, -285, -305
First Floor		
3	RC column - Room No 29	-186, -172, -215, -184, -224, -269, -211, -192, -205, -154
4	RC beam - Room No 27	-225, -220, -262, -254, -264, -250, -214, -228, -232, -280
Second Floor		
5	RC column – Near Bathroom	-350, -321, -386, -255, -290, -386, -399, -316, -350, -300
6	RC slab – Good location	-277, -205, -256, -222, -290, -200, -224, -250, -184, -199
7	RC slab – Room No 46 - Damaged	-350, -306, -388, -390, -324, -379, -300, -301, -290, -300

5.4 Evaluation of Chlorides and pH

Concrete samples in powder form were drawn from 6 selected RC structural elements of the various floors using a masonry drilling machine **(Photo 9)**. These samples were collected for chemical analysis to check for the presence of aggressive chemical agents, such as, chlorides and pH. **Table 4** gives the results of chloride and pH levels in concrete for the 6 locations of the RC structural elements of the various floors.

Photo 9 A view of the powder sample was extracted from a RC column

Table 4 Results of Chloride Test & pH

Sl. No.	Member Identification	Chloride Content in (kg/m^3)	pH	Stipulation
1	RC column - Room No 1 - Ground Floor	0.5	11.93	Maximum Chloride content in concrete shall not exceed 0.6 kg/m^3 by weight of concrete at the time of placing as per IS: 456-2000.
2	RC beam - Room No 1 - Ground Floor	0.3	12.20	
3	RC column - Room No 29 - 1st Floor	0.9	11.18	
4	RC beam - Room No 27 - 1st Floor	0.8	11.52	
5	RC column - 2nd Floor - Near Bathroom	0.6	11.71	
6	RC slab - Room No 46 - 2nd Floor	0.4	12.12	

6.0 EVALUATION OF THE TEST RESULTS

The results of the NDT tests conducted in the RC structural elements of the various floors of the Working Women's Hostel Building are discussed in the following sections.

6.1 Tests on the Concrete Core Samples

6.1.1 Assessment of carbonation

The concrete core samples, immediately after extraction were tested for carbonation. It is seen from **Table 1** that the carbonation depth of the concrete core samples extracted from the 6 RC structural elements varies between 20 mm and 240 mm.

6.1.2 Compressive strength test

The concrete core samples were subjected to compressive strength test in a Universal Testing Machine of 1000 kN capacity. Results of the compressive strength tests of core samples are given in **Table 1**.

The equivalent cube compressive strength of concrete in the 6 RC structural elements are 25.9 MPa, 7.3 MPa, 8.6 MPa, 24.0 MPa, 10.1 MPa and 14.8 MPa respectively. This may be submitted to the designer/consultant for his comments.

6.2 Half Cell Potential Test

It is seen from **Table 3** that the half-cell potentials in a majority of the locations of the selected RC structural elements of the ground floor and 1st floor as well as the good location of the RC slab in the second floor are between -200 mV and – 350 mV indicating that the corrosion activity of the reinforcing steel in the area is uncertain at the time of measurement as per the reference guidelines of ASTM C-876.

It is seen from **Table 3** that the half-cell potentials in the remaining locations of the structural elements of the second floor are above – 350 mV indicating that there is a greater than 90 % probability that reinforcing steel corrosion is occurring in that area at the time of measurement as per the reference guidelines of ASTM C-876.

6.3 Chemical Analysis of Concrete Powder Samples

It is found from **Table 4** that the chloride contents of the samples drawn from the 6 selected RC structural elements of the various floors are in the range of 0.3 to 0.9 kg/m^3 compared to a permissible value of 0.6 kg/m^3 at the time of placing as specified in IS: 456-2000 **[2]**.

The pH of the concrete samples extracted from the 6 selected RC structural elements of the various floors is between 11.18 and 12.20 and this indicates a marginal reduction in alkalinity.

7.0 RECOMMENDATIONS

It was observed from the visual observations that the distress was mostly confined to the second floor roof slab probably due to damaged weathering course and consequent water seepage from the terrace of the building. At the time of the inspection, the damaged weathering course is being removed and action has been initiated for the waterproofing.

The half-cell potentials in most of the RC Structural elements in the second floor are above –350 mV indicating that there is a greater than 90 % probability that reinforcing steel corrosion is occurring in that area at the time of measurement as per the reference guidelines of ASTM C-876. The chloride contents in the RC structural elements are in the range of 0.3 to 0.9 kg/m^3 compared to a permissible value of 0.6 kg/m^3 at the time of placing as specified in IS: 456-2000. The pH of the concrete samples in the RC structural elements indicates a significant reduction in the alkalinity.

The corrosion of the rebars may be attributed to the ingress of both chlorides and carbon di oxide. The carbonation test also revealed that diffusion of carbon di oxide front has reached the rebars.

Hence, it is recommended to rehabilitate the minor distress noticed in the RC Structural Elements in the various floors using Polymer Modified Mortar as per the **Methodology A** given in **Annexure I**.

It is also recommended to rehabilitate the severely distressed RC Slab in the second floor using Micro Concrete Jacketing as per the **Methodology B** given in **Annexure I**.

In view of the low equivalent cube compressive strengths of the concrete obtained in the RC columns and RC beams, the opinion of the Designer/consultant may be obtained to increase the load carrying capacity of the RC columns and RC beams through Micro

Concrete Jacketing or Carbon Fibre Reinforced Plastics (CFRP) Wrapping. The rehabilitation methodology for the Micro concrete jacketing is given in **Methodology C & D** in **Annexure I.** The rehabilitation methodology for CFRP wrapping is given in **Methodology E** in **Annexure I**.

8.0 CONCLUDING REMARKS

Based on the results of the core drilling test, carbonation test, Half-cell potential test and powder sample test carried out on the RC structural elements of the various floors of the Working Women's Hostel Building of the SWD at Adyar, Chennai and the following conclusions are made:

- The carbonation depth of the concrete core samples extracted from the 6 RC structural elements varies between 20 mm and 240 mm.
- The equivalent cube compressive strength of concrete in the 6 RC structural elements are 25.9 MPa, 7.3 MPa, 8.6 MPa, 24.0 MPa, 10.1 MPa and 14.8 MPa respectively. This may be submitted to the designer/consultant for his comments.
- The half-cell potentials in a majority of the locations of the selected RC structural elements of the ground floor and 1st floor as well as the good location of the RC slab in the second floor are between -200 mV and – 350 mV indicating that the corrosion activity of the reinforcing steel in the area is uncertain at the time of measurement as per the reference guidelines of ASTM C-876.
- The half-cell potentials in the remaining locations of the structural elements of the second floor are above – 350 mV indicating that there is a greater than 90 % probability that reinforcing steel corrosion is occurring in that area at the time of measurement as per the reference guidelines of ASTM C-876.
- The chloride contents of the samples drawn from the 6 selected RC structural elements of the various floors are in the range of 0.3 to 0.9 kg/m^3 compared to a permissible value of 0.6 kg/m^3 at the time of placing as specified in IS: 456-2000.
- The pH of the concrete samples extracted from the 6 selected RC structural elements of the various floors is between 11.18 and 12.20 and this indicates a marginal reduction in alkalinity.
- It is recommended to rehabilitate the minor distress noticed in the RC Structural Elements in the various floors using Polymer Modified Mortar as per the **Methodology A** given in **Annexure I**.
- It is also recommended to rehabilitate the severely distressed RC Slab in the second floor using Micro Concrete Jacketing as per the **Methodology B** given in **Annexure I**.

- In view of the low equivalent cube compressive strengths of the concrete obtained in the RC columns and RC beams, the opinion of the Designer/consultant may be obtained to increase the load carrying capacity of the RC columns and RC beams through Micro Concrete Jacketing or Carbon Fibre Reinforced Plastics (CFRP) Wrapping. The rehabilitation methodology for the Micro concrete jacketing is given in **Methodology C & D** in **Annexure I.** The rehabilitation methodology for CFRP wrapping is given in **Methodology E** in **Annexure I**.

Annexure I

Rehabilitation Methodology

Methodology A

Isolated Patch Repair using Polymer Modified Mortar

Stage 1

Remove the damaged concrete portions in the RC elements completely till the reinforcement is exposed from the member carefully with mechanical arrangements and hand chiselling. Clean the surface to remove loose dust/particles.

Stage 2
Application of anti-corrosive coating

Clean the reinforcement and apply the anticorrosive coating like Nitozinc primer (manufactured by M/s Fosroc Chemicals or equivalent). In case the existing rods have undergone 30% loss in diameter, provide additional reinforcement and suitably connect it to the core concrete through shear connectors.

Stage 3
Provision of epoxy jointing compound

Prepare the surface suitably using an epoxy-based bond coat like Nitobond EP (manufactured by M/s Fosroc Chemicals or equivalent) so that the repair material may bond well with existing /old concrete. Manufacturer's instructions/ specifications are to be followed for the epoxy bond coat.

Stage 4

After the application of the bond coat, Polymer Modified Mortar (Nitobond SBR manufactured by M/s Fosroc chemicals or equivalent) may be prepared as follows:

- Cement and sand (sieved) shall be mixed in the ratio of 1:3 and 1 litre of Nitobond SBR per bag of cement (or any equivalent product) shall be added to the above mortar mix and applied to the primed concrete surface using a trowel. The dosage of SBR shall be 1 litre per bag of cement.

Stage 5

- The surface shall be finished neatly to the required line and length and cured.

Methodology B

Rehabilitation of corroded slab using micro-concrete jacketing

Concrete jacketing for the slab

1. Strengthening is to be done using micro concrete.
2. Provide cores from the slab of about 77 mm diameter to facilitate the pouring of micro concrete.

Stages of repair

Stage 1

Remove the damaged concrete portions completely till the reinforcement is exposed from the member carefully with mechanical arrangements and hand chiselling. Clean the surface to remove loose dust/particles.

Stage 2
Anchoring shear connectors into existing slab

1. Shear connectors in the form of 'L-shaped' bars has to be anchored into the existing concrete to ensure integral action of the reinforced concrete jacket portion with the hardened core concrete of the existing beam.
2. Drill holes not less than 75 mm depth (long) into the members from the surface (Perpendicular to the surface) taking care not to damage the existing steel reinforcements in the column. The positioning of the holes has to be staggered along the perimeter and length of the beam.
3. Clean the holes with a jet of compressed air and remove the loose dust particles thoroughly.
4. Use chemical resin type capsules (Lokfix S manufactured by M/s Fosroc Chemicals (I) Pvt. Ltd or equivalent) for anchoring/fixing dowel bars into the holes to serve as shear connectors.
5. Adopt at least 10-mm dia. HSD bars as shear connectors for which 12 mm dia holes may be needed.
6. Provide additional reinforcement in case the existing rods have undergone 30% loss in diameter.
7. The additional reinforcement will be connected to the shear connectors already provided

Stage 3

Application of anti-corrosive coating

Apply the metallic based (preferably zinc based) anticorrosive coating like Nitozinc primer (manufactured by M/s Fosroc Chemicals or equivalent) to the old and new reinforcement after cleaning them.

Stage 4

Provision of Galvanic protection

Provide Galvanic protection system like Galvashield XPI or equivalent as per the design spacing based on the percentage of reinforcement available in the RC elements.

Stage 5

Provision of epoxy jointing compound

Prepare the slab surface suitably using an epoxy based bond coat like Nitobond EP (manufactured by M/s Fosroc Chemicals or equivalent), so that the jacketed concrete may bond well with existing/old concrete. Manufacturer's instructions/specifications are to be followed for the epoxy bond coat.

Stage 6

Provision of water tight shuttering

Suitable shuttering (leak proof) system has to be placed in position for the jacket portion of the member in stages and micro concrete as per specifications has to be placed into the form work of the jacket portion. Care has to be taken so that the micro-concrete used does not flow out of the shuttering.

Stage 7

The preparation of the micro concrete (Rendroc RG manufactured by M/s Fosroc Chemicals or equivalent), placing, compaction and curing for the same should be as per manufacturers specification. The micro concrete may be placed using the 77 mm diameter cores already provided in the RC slab. The micro concrete used for jacketing should have a minimum characteristic compressive strength of 45 MPa at 28 days. Cure the same after removal of the shutter.

Stage 8

After the concrete in the jacket portion of the slab in the particular stage has attained its strength, the props placed for supporting the corresponding beams are to be removed.

Methodology C (to be decided by the Designer/Consultant)

Rehabilitation of RC Column by Micro Concrete Jacketing

Micro concrete jacketing for RC columns

1. Strengthening is to be done using micro concrete
2. Support the slab & beam which is contributing the load for the column under rehabilitation.

Stages of repair

Stage 1

- Remove the damaged concrete portions completely till the reinforcement is exposed from the member carefully with mechanical arrangements and hand chiselling. Clean the surface to remove loose dust/particles.

Stage 2
Anchoring shear connectors into existing column

- Shear connectors in the form of 'L-shaped' bars has to be anchored into the existing concrete to ensure integral action of the reinforced concrete jacket portion with the hardened core concrete of the existing column.
- Drill holes not less than 75 mm depth (long) into the members from the surface (Perpendicular to the surface) taking care not to damage the existing steel reinforcements in the column. The positioning of the holes has to be staggered along the perimeter and height of the column. The vertical spacing of shear connectors should be less than 300 mm for all the sides of the member.
- Clean the holes with a jet of compressed air and remove the loose dust particles thoroughly.
- Use chemical resin type capsules marketed by reputed firms. (E.g. Fosroc Chemicals (I) Pvt. Ltd. or equivalent) for anchoring/fixing dowel bars into the holes to serve as shear connectors.
- Adopt at least 10-mm dia. HSD bars as shear connectors for which 12-mm dia holes may be needed.
- Provide additional main and shear stirrup reinforcement in case the existing rods have undergone 30% loss in diameter.
- The additional reinforcement may be connected to the shear connectors already provided

Stage 3
Application of anti-corrosive coating

- Clean the reinforcement and apply the anticorrosive coating like Nitozinc primer manufactured by M/s Fosroc Chemicals or equivalent as per the standard manufacturer's specification.

Stage 4

Provision of epoxy jointing compound

- Prepare the columns surface suitably using an epoxy-based bond coat, so that the jacketed concrete may bond well with existing/old concrete. Manufacturer's instructions/specifications are to be followed for the epoxy bond coat like Nitobond EP manufactured by M/s Fosroc Chemicals or equivalent.

Stage 5

Provision of water tight shuttering

- Suitable shuttering (leak proof) system has to be placed in position for the jacket portion of the members in stages and micro concrete as per specifications has to be placed into the form work of the jacket portion. Care has to be taken so that the micro-concrete used does not flow out of the shuttering.

Stage 6

- The preparation of the micro concrete (Rendroc RG manufactured by M/s Fosroc Chemicals or equivalent), placing, compaction and curing for the same should be as per manufacturers specification. The micro concrete used for jacketing should have a minimum characteristic compressive strength of 45 MPa at 28 days.

Stage 7

- After the concrete in the jacket portion of the columns in the particular stage has attained its strength, the props placed for supporting the corresponding beams are to be removed.

Methodology D (to be decided by the Designer/Consultant)

Rehabilitation Methodology for Beam using Micro Concrete Jacketing

Concrete jacketing for the beams

1. Strengthening is to be done using micro concrete
2. Support the slab which is contributing the load for the beam under rehabilitation.
3. Provide cores from the slab of about 77 mm diameter to facilitate the pouring of micro concrete.

Stages of repair

Stage 1

Remove the damaged concrete portions completely till the reinforcement is exposed from the member carefully with mechanical arrangements and hand chiselling. Clean the surface to remove loose dust/particles.

Stage 2

Anchoring shear connectors into existing beam

1. Shear connectors in the form of 'L-shaped' bars has to be anchored into the existing concrete to ensure integral action of the reinforced concrete jacket portion with the hardened core concrete of the existing beam.
2. Drill holes not less than 75 mm depth (long) into the members from the surface (Perpendicular to the surface) taking care not to damage the existing steel reinforcements in the column. The positioning of the holes has to be staggered along the perimeter and length of the beam.
3. Clean the holes with a jet of compressed air and remove the loose dust particles thoroughly.
4. Use chemical resin type capsules (Lokfix S manufactured by M/s Fosroc Chemicals (I) Pvt. Ltd or Equivalent) for anchoring/fixing dowel bars into the holes to serve as shear connectors.
5. Adopt at least 8-mm dia. HSD bars as shear connectors for which 12-mm dia holes may be needed.
6. Provide additional main and shear stirrup reinforcement in case the existing rods have undergone 30% loss in diameter.
7. The additional reinforcement may be connected to the shear connectors already provided

Stage 3

Application of anti-corrosive coating

Clean the reinforcement and apply the anticorrosive coating like Nitozinc primer (manufactured by M/s Fosroc Chemicals or equivalent) to the old and new reinforcement.

Stage 4

Provision of epoxy jointing compound

Prepare the beam surface suitably using an epoxy based bond coat like Nitobond EP (manufactured by M/s Fosroc Chemicals or equivalent), so that the jacketed concrete may bond well with existing/old concrete. Manufacturer's instructions/specifications are to be followed for the epoxy bond coat.

Stage 5

Provision of water tight shuttering

Suitable shuttering (leak proof) system has to be placed in position for the jacket portion of the members in stages and micro concrete as per specifications has to be placed into the form work of the jacket portion. Care has to be taken so that the micro-concrete used does not flow out of the shuttering.

Stage 6

The preparation of the Micro concrete (Rendroc RG manufactured by M/s Fosroc Chemicals or equivalent), placing, compaction and curing for the same should be as per manufacturers specification. The micro concrete used for jacketing should have a minimum characteristic compressive strength of 45 MPa at 28 days. Cure the same after removal of the shutter.

Stage 7

After the concrete in the jacket portion of the beam in the particular stage has attained its strength, the props placed for supporting the corresponding beams are to be removed.

Methodology E

Strengthening of RC Columns/RC Beams using CFRP Wrapping (to be decided by the Designer/Consultant)

Stage - 1

- Carry out surface preparation by grinding the surface to get an even surface. All projections are to be grounded off. All the corners should be grounded to a radius of min 25 mm to 50 mm to have proper effect of wrapping .

Stage - 2

- Apply epoxy primer like Nitowrap 30 manufactured by M/s Fosroc chemicals or equivalent to the prepared concrete surface. Apply Nitocote VF manufactured by M/s Fosroc chemicals or equivalent to fill all pin/blow holes and inner radius to be made curve and on all concave areas in order to have full contact of wrap with concrete surface. Apply 1st coat of saturant Nitowrap 410 manufactured by M/s Fosroc chemicals or equivalent by roller or brush. Based on design recommendation, type and orientation required, cut the fiber into required size and place on saturant and press by rollers to squeeze out the saturant through the fabric. Apply 2nd coat of saturant to saturate the fabric fully. The Manufacturers specifications shall be followed strictly.

- Further, more layers of wrapping, if required, can be carried out in similar manner as above except surface preparation.

Stage - 3

- Final coat of saturant should be sprinkled with quartz sand to have a mechanical bond with further protective plaster or should be coated with protective coating directly.

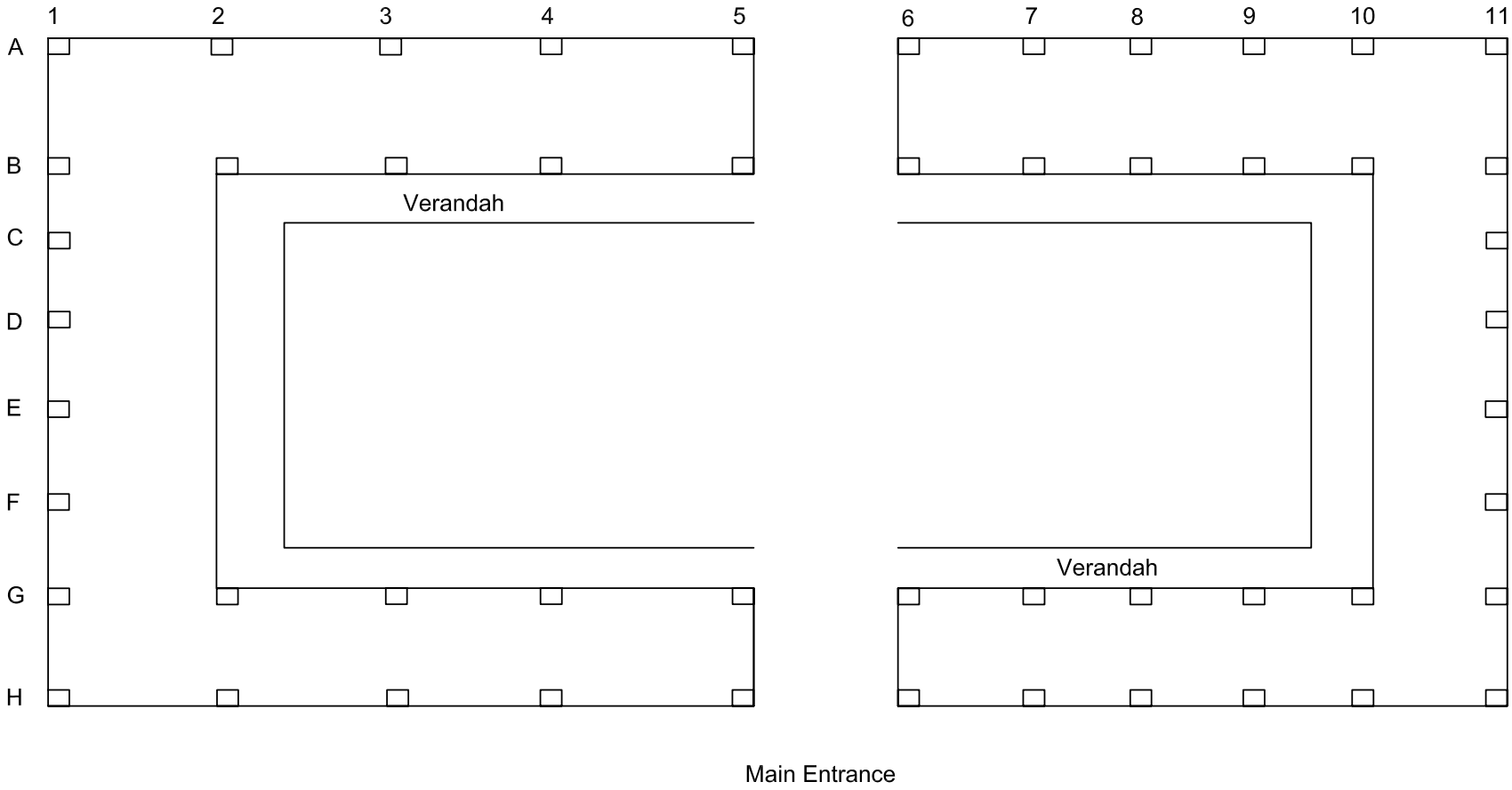


Fig. 1 Typical Layout of the Working Womens Hostel Building

CHAPTER-XVII

REPORT OF THE ONE MAN COMMITTEE ON THE COLLAPSE OF THE ROOF OF BUS STAND LOCATED IN SOMANUR HAMELT OF KARUMATHAMPATTI TOWN PANCHAYAT, COIMBATORE DISTRICT ON 07-09-2017

A meeting was conducted on 02.11.2017 with the following Department's technical officials and suggestions for guidelines to be followed were obtained.

1. Directorate of Rural Development and Panchayat Raj.
2. Commissionerate of Municipal Administration.
3. Directorate of Town Panchayats.

The suggestions and recommendations made by the above three Departments are briefed below:-

1. Directorate of Rural Development and Panchayat Raj:-

a) Proper soil test should be conduted before commencement of construction work and the test results should be got vetted by reputed Institutions.

b) Buildings should be properly designed by considering Stability, Strength and Serviceability criteria. A strict Quality Control Mechanism is to be followed during execution.

c) After the construction is over, routine periodical maintenance should be carried out. Buildings more than 10 years old should be inspected twice and less than 10 years once by the Assistant Engineer and necessary Stability Certificate to be sent to Assistant Executive Engineer concerned.

d) For demolishing the old buildings, necessary rules and regulations with delegation of powers should be issued.

2. Commissionerate of Municipal Administration:-

a) A history register for every public building should be maintained and a District wise Technical Committee should be formed for proper upkeep of the structures.

b) It is also suggested that a Maintenance Check List shall be prepared in consultation with Public Works Department.

c) Responsibility should be fixed on the concerned officers to inspect the building once in three months and to rectify the defects, if any.

d) Any additional construction proposal should be sanctioned only after getting Inspection Report from the officer concerned.

e) Third Party Inspection Report should be availed before issuing of Completion Report of any new building.

f) Electrical Wiring Arrangements should be periodically verified and certified by the “B” Licence holder.

g) Operation and Maintenance of the Public buildings should be out-sourced.

3. Directorate of Town Panchayats:-

a) All the Public buildings should be verified by the concerned Engineers for the stability.

b) The Field Engineers should inspect all the public buildings once in a year and report that the building is safe to Director of Town panchayats through the District Collector.

c) Register of Public Buildings should be maintained in the Town Panchayat office.

d) Any deficiency found in the structure should be intimated to the Executive Engineer and immediate rectification should be done by the Executive Engineer.

e) No alterations of additions of the existing structure shall be permitted to the lessees without permission of the concerned engineers.

f) A Quality Control Wing should be formed to enforce quality and structural stability of the existing public buildings.

g) Day to Day repairs should be properly carried out and special repairs should be carried out to prevent deterioration of old buildings.

h) Proper budget provisions has to be made every financial year.

Based on the detailed discussions held with various technical officers and based on the suggestions summarized above, the following recommendations are given by the One Man Committee for ensuring that in future such accidents in the public buildings are avoided as far as possible.

Recommendation 1 :

Technical Hand Books for the reference of Technical Officers to be brought out by each Department:-

The Committee observed that for bus stands of similar area, different designs were used by different Town Panchayats within the Coimbatore District itself. Further, there is no uniformity of designs available for construction of bus stands with the local bodies in general. Each time, the design of the bus stand varies in accordance with the decisions of the technical officers of the jurisdiction and site conditions. The design of the Canopy structure of the Somanur Bus Stand of Karumathampatti Town panchayat was faulty. If the officers in the field do not have sufficient experience in structural designs, it will end up in construction of faulty structures endangering the safety of common public. The

Directorate of Rural Development has been bringing out Technical Hand Books of buildings and of Roads and Bridges wherein the designs for various buildings such as Passenger Shelters, Community Halls, School Buildings, Village Administration Office buildings, School Toilets, Combined Self-Help Group and Panchayat Level Federation Buildings, Panchayat Office Buildings are given along with the structural details. The above Booklets also give recommendations of Structural Elements, Column Reinforcement details, Beam-Column details, Beam-Reinforcement details, Cantilever Beam Reinforcement details, One Way Slab-Reinforcement details, Two Way Slab Reinforcement details, Staircase Reinforcement details etc.

The Technical Hand Book of Roads and Bridges of Directorate of Rural Development has also standardized the specifications and geometric designs of public structures such as Causeway and Submersible Bridges, Culverts, embankments, pavements, road and bridges. Various quality control parameters have also been stipulated in the above Technical Hand Books. The tests that are to be carried out during the construction and post construction are also specified. The above system of standardizing the basic type of designs and structural designs for various public buildings and structures is essential for all local bodies as well as technical departments, such as Public Works Department and Highways Department.

Summary of Recommendations 1 :

It is recommended that each department constructing buildings for public usage (such as Municipal Administration and Water Supply Department, Rural Development and Panchayat Raj, Public Works Department, Highways Department, Housing and Urban Development Department, Health Department, School Education and Higher Education Department) should bring out Technical handbooks to be distributed to the field officers (which should be also periodically updated) which stipulate the basic type designs and structural details and minimum safety stipulations of standard buildings and structures such as Bus Stands, Public Shelters, Schools and College buildings, Taluk Offices, Block Offices, Local Body Offices, bridges and culverts, so that the basic safety stipulations are ensured within the standard type of designs and based on the local site conditions, additional safety features can be incorporated by the Field Officers.

Recommendation 2 :-

Structural Design of buildings of public usage especially with Cantilevers to be vetted by Technical Officers at senior level:-

The Structural Design of buildings of mass public usage should not only conform to the minimum stipulations as specified for the type of building by the department concerned in its standard technical manuals, but also satisfy the three fundamental requirements of Stability, Strength and Serviceability. (i) The designs parameters like grade of concrete and steel assumed in the design should conform to the requirements exactly at the construction stie. (ii) Further, the seismic factors should also be taken into consideration and seismic disaster-resistant construction designs should be ensured by competent Technical Officers of sufficient seniority level or by reputed institutions as may be stipulated by the department concerned. (iii) As far as the Cantilever structures are

concerned, it is important that the type design and structural parameters of buildings of cantilever structures should be approved only by senior and competent technical officers (at least of the SE Level) irrespective of the cost of the building if the building is to be used by the public en-masse. In other words, even if the structure to be built is of a value that can be approved by, say an Assistant Executive Engineer (AEE) level officer, it is better to get the approval by a senior (say Superintending Level officer) in view of the cantilever structure being there in the design.

Summary of Recommendation 2:

Each Technical department should, through a formal order, ensure that the structures of mass public usage have seismic-disater-resistant factors of consideration. Further, if the structure concerned has long cantilever portions (over 1.5 m length or 5 feet) in the design (other than window / ventilator shades which, in any case, are shorter than 1.5 m), the department concerned should formally designate the seniority of the technical officer (at least SE level suggested) or the Category of institution who / that will vet and approve the structural design of the structure so that any sort of deficiencies or errors in the design process are totally avoided. This technical approval should be irrespective of the cost of the structure.

Recommendations 3:-

Need to formally stipulate the minimum technical tests to carry out while constructing the structures:-

Since the public structures like Bus Stand, Community Halls and other such buildings are used by common public en-mass on day-to-day basis, it is extremely important for each department to stipulate minimum tests that are to be conducted to verify the quality of (a) Cement used, (b) Sand used for construction, (c) Coarse Aggregate utilized; (d) bricks; (e) Steel Reinforcement and (f) water utilized, etc. Also, Concrete Cube Test be done which is necessary to ascertain the quality and strength of concrete.

Summary of Recommendation 3:

In summary, each department should also formally recommend certain stipulated tests to be compulsorily carried out for each public building structure to test the quality of Sand, Cement, Water, Steel and Reinforced Cement Concrete which should be compulsorily be conducted, the test results got and such results should be within the prescribed technical parameters before the contractor is paid the money for the work.

Recommendation 4:-

Cautions to be used in utilizing the existing Cantilever structures in Public Buildings:-

The Cantilever Structures are one of the weakest links in any public building. The cantilever structure in the Somanur bus stand of Karumathampatti Town Panchayat fell down which caused accident resulting the injuries and death to the common public. Long Cantilever structures (except Windows, Sunshades and Ventilator etc) made by Reinforced Cement Concrete should be avoided as far as possible since this become weak with the passage of time. If, in any case, long cantilever structures and constructed

based on the necessity at site, such structures should not be loaded with extra weight so as to cause accidents.

Summary of Recommendation 4:

Any kind of overloading should be avoided on canopy or cantilever structures in the public buildings and structures / situations like the following be avoided:-

I. Construction of parapet wall on the free end of canopy.

II. Providing Over Head Tanks on the Canopy Projection.

III. Stagnation of water on the terrace of canopy portion.

IV. Free and Easy access of the common public to the Canopy.

V. Providing Advertisement Boards over the Canopy.

VI. Providing flower pots on the canopy.

VII. Providing lamp posts / High Mast Lights to get a good coverage for lighting.

VIII. Dumping of unwanted things / debris on the Canopy.

IX. Carrying out repair works without proper supports below the beams / slab of canopy.

X.

Recommendation 5:-

Need for stipulating periodical maintenance of the buildings:-

Any building constructed with meticulous care and excellent finish is to be kept up well and maintained properly to serve the purpose for which it was put up. The environment does have profound effect on buildings. Hence, problems arising out of this and other operation & maintenance problems, need to be taken care to prevent decay and deterioration of the building.

Generally, these aspects are adequately taken care of at the design and construction stages, with appropriate factor of safety. Nevertheless, due to bad workmanship, and poor supervision, maintenance problems do crop up.

The following are the reasons for progressive collapse of the building that need to be addressed immediately with utmost care during maintenance of the buildings.

- Diagonal wall crack - Foundation designs has to be checked whether differential settlement of the building occurs if any.
- Deflected, buckled or crushed beams or columns.
- Cracked, broken, spalled or undermined concrete.
- Corrosion of steel reinforcement - Exposure of steel to the environment leads to failure of structural components like Beams, Columns and slabs.
- Water logging over the Roof slab – Dampness in the roof slab reduces the strength of the concrete which requires periodical cleaning of debris over the roof for effective draining of rain water.

During the above technical inspections, the following features should be inspected and incorporated in the format to be specified by the Department:

I. The roofs are to be cleaned and debris removed from the roof to avoid blockages in roof gutters and rain water pipes prior to onset of monsoon. Rainwater inlets should be checked and ensured that there are no damages around these. This should be verified in the technical inspection.

II. The field engineer is expected to carry out, with reasonable diligence, a visual inspection of

a) The Condition of the structure of the building

- to indentify the types of structural defects
- to identify any signs of structural distress and deformation
- to identify any signs of material deterioration

b) The loading on the structure of the building - to identify any deviation from intended use, misuse which can result in overloading.

c) Any addition or alteration works affecting the sructure of the building - to identify any addition or alteration works which can result in overloading or adverse effects on the structure.

III. In case of major structural defects, the scope of the full structural investigation should include the following:

a) Carrying out tests on the materials used and structural elements of the building;

b) Carrying out load test on parts of the building if necessary;

IV. In case there are doubts about structural soundness of a building, the same should be brought to the notice of higher authorities on a priority basis so as to take prompt remedial action.

V. If any signs of significant structural deterioration or defects are present, the field engineer should make an assessment of the deterioration or defect and report to the next higher authority for further action. The next higher authority should inspect all the buildings with major/minor structural defects within one month alongside reports of field level engineers. He / She should report the fact with specific remarks to the District Collector/ Department Head for further action.

VI. Records of observations of any signs of structural defects, damages, distress, deformation or deterioration of the building should include the following Major, Minor structural defects and non-structural Defects.

- Cracks in Walls
- Cracks in RCC Slab,
- excessive deflection of beams,
- instability,
- foundation settlement,
- spalling concrete,
- corrosion of steel,
- Dampness in Roof salb, Wall if any

VII. Based on the severity of defects found, immediate maintenance work / rectification work should be carried out by the department concerned.

Summary of Recommendation 5:

It is recommended that for all buildings of mass public usage such as Bus Stands, Community Halls, Staircases etc., periodical structures inspections should be carried out at least by the Assistant Executive Engineeer level officer of a the area jurisdiction every year at least once and preferably before the end of September (i.e. before the onset of monsoons) and an Inspection format should be stipulated by the department with a model check list which should incorporate technical parameters to be noted for both visual inspection as well as field structural investigation of the building concerned. The above Inspection Notes should be forwarded to the superior Technical Officers and the conduct of inspection should be monitored at the highest level in order to ensure that no unsafe public buildings go uninspected and undetected by the officials concerned.

Recommendation 6:-

Structural Audit of Old Structures:

There are number of public buildings which have age of more than 30 years and whose strength might have reduced due to material deterioration. Based on the yearly tests of each public building to be carried out, the weaker buildings which are more than 30 years old be identified and the Assistant Executive Engineer level Officer of the department concerned should forward the list to the superior officer of the level of EE/SE. Thereafter, an inspection at the level of Superintending Engineer / EE should be carried out for all such buildings and a through the structural audit should be undertaken. The department concerned should consider entrusting the Structural Audit to be also carried out through a suitable Approved Institution / agency and the details of which are suggested as under:

Generally, the Structural Audit is carried out and the steps to be followed in Structural Auditing are as under:

STEP 1:

It is imperative that Architectural and Structural plans of the building are essential. It will be helpful if detailed structural calculations including assumptions for the structural design are made available.

STEP 2:

If the Architectural plans and Structural plans are not available, the same can be prepared based on the site observations.

STEP 3:

Inspection of the Building – A detailed inspection of the building can reveal the following:

16. Any settlement in the foundations.
17. Cracks in columns, beams and slabs.
18. Concrete disintegration and exposed steel reinforcements photographs can be helpful.
19. Slight tapping using hammer can reveal deterioration in concrete and wooden beams in Madras Terrace roofs.
20. Corrosion in reinforcement.
21. Status of Balconies – sagging, deflection, cracks.
22. Status of Architectural features.
23. Cracks in walls indicating swelling in R.C.C members or defection of corrosion.
24. Leakages from terrace & Toilet blocks.
25. Leakages & dampness in walls resulting into cracks and corrosion.
26. Status of repairs & last repaired date.
27. What portion of the structure was repaired?
28. Who was the Agency?
29. How much was spent for repairs?
30. Are approved Building plans available?

STEP 4:

Preparation of Audit Report:

On the basis of inspection on building, an Audit Report is prepared.

STEP 5:

Tests Recommended:

It is important that various tests are carried out in the old buildings. This will give an idea about the extent of corrosion, distress and loss of strength in concrete & steel.

STEP 6:

Highlight the critical areas and how to go for repairs.

METHODOLOGY

3. Destructive Testing:

To verify the integrity of a component, it is always possible to cut or section through the components and examine the exposed surfaces. Components can be pulled or stressed and pressurized until failure to determine their properties of strength and toughness. Materials can be chemically treated to determine their composition. These are some forms of destructive testing. Unfortunately this approach of destructive testing renders the component useless for its intended use as against non-destructive testing which can be performed on the components and machines without affecting their service performance.

4. Non Destructive Testing:

Non-Destructive Testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms Non-destructive examination, Non-destructive inspection and Non-destructive evaluation are also commonly used to describe this technology, because NDT does not permanently alter the component being inspected, it is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research. Common NDT methods the following:

9) Rebound Hammer Test.

10) Ultrasonic pulse Velocity (UPV) Tests.

11) Evaluation of the equivalent cube compressive strength of concrete by conducting tests on the core samples.

12) Carbonation Test.

13) Half-cell potential Test.

14) Evaluation of Chlorides and PH through concrete powder samples.

15) Profoscope Survey.

16) Tests on Reinforcing steel rebars.

Summary of Recommendation 6:

Based on the yearly inspection of the Public structures, structural Audit may be carried out of such buildings that are over 30 years of age and also found to be structurally weak in the inspection and such other special cases where there is an urgent necessity to conduct the structural Audit irrespective of the age of the building. Thereafter, decision may be taken by the administrative agency concerned to strengthen the building to ensure safety or instead, go for its demolition.

Recommendation 7:-

Need to keep a Register of Public Buildings with updated details of additions undertaken in the building:

Since there are structural additions in each building, it is important that each Local Body / Technical Department should have a register of the Public Buildings wherein additions made in the above buildings or updated or incorporated in the register concerned. Further, based on the technical inspection carried out each year (before the end of September i.e. onset of monsoon), if any weaker sections are noticed, precautionary measures to be undertaken pertaining to such structures should be incorporated in the above register of public buildings by the serving technical officer of the jurisdiction for guidance of the officers succeeding him. This will ensure the safety of the building and such data will be helpful in future for carrying out any precautionary measures.

Summary of Recommendation 7:

In summary, the construction and maintenance history of each building should be maintained separately in the register of Public Buildings and important precautions as prescribed based on the yearly inspections or the structural audit as the case may be, should also be incorporated in the register for each building as per local requirements.

Recommendation 8:-

Departments to formulate standard procedures to be followed for demolition of old / damaged buildings which cannot be rectified:

Each Department should, through a Government Order or Circular at the highest level, bring out guidelines for delegation of powers for demolition of old buildings which are not safe and non-rectifiable. In this regard, the Public Works Department and the Directorate of Rural Development and Panchayat Raj have already brought out the Government Orders for delegation of powers for demolition of old damaged buildings / non-rectifiable buildings.

Summary of Recommendation 8:

In order to enable the field level staff to take quick action wherever demolition is required and in order to shorten the long drawn process of getting permissions, the departments should streamline the procedures specifying the guidelines for demolition of old buildings through a Government Order or Circular in this regard.

Recommendation 9:-

Training of Technical officers:

It is extremely important that the technical officers in the field should be trained regarding the latest technology for construction and structural design including foundation design along with the latest changes in the technology in the construction and design of buildings especially in the structures which are to be used by the public at large. Hence, it is recommended that each Technical Officer from the level of at least Junior Engineer and above should be trained at least once in a year about the latest technologies pertaining to Soil Foundations, Structural Engineering, safety features, upkeep of Public buildings, incorporation of seismic resistant features in the buildings etc. The training of the technical officers concerned may be undertaken by the department either in the training institutions or in coordination with the local Government Engineering Colleges / Polytechnics in the district itself.

Summary of Recommendation 9:

It is stipulated that all the technical officials of the departments should be trained at least once a year with the latest knowhow in the building technologies and the proper upkeep and maintenance of structures.

CHAPTER-XVIII

BIBLIOGRAPHY

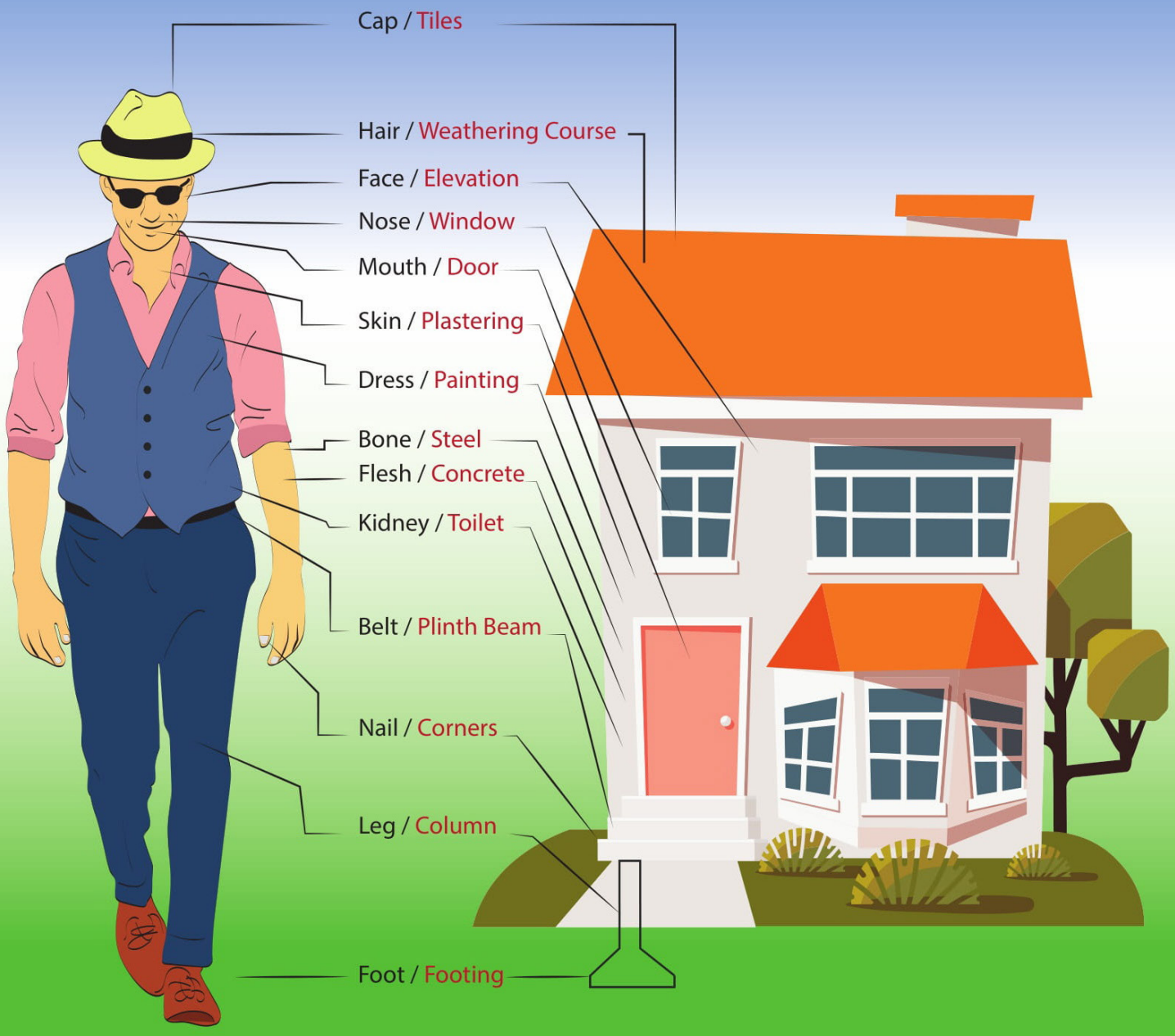
Relevant IS codes

1. IS 456: 2000 “Plain and Reinforced Concrete- Code of Practice”, Bureau of Indian Standards, New Delhi 6
2. SP : 34 (S &T) -1987 “Hand Book on Concrete Reinforcement and Detailing” Bureau of Indian Standards, New Delhi 6
3. SP 16 “Design Aids for Reinforced Concrete to IS 456 “Bureau of Indian Standards, New Delhi 6
4. IS 875 “Code of Practice for Design Loads “Bureau of Indian Standards, New Delhi 6
5. IS: 13311 (Part I): 1992, “Non-destructive Testing of Concrete -Methods of Test”, Bureau of Indian Standards, New Delhi 6
6. IS: 13311 (Part II): 1992, “Non-destructive Testing of Concrete -Methods of Test”, Bureau of Indian Standards New Delhi 6
7. IS: 1786: 2008 “High Strength Deformed Steel Bars and Wires for Concrete reinforcement—Specification” Bureau of Indian Standards,
8. SP 25: 1984 Causes And Prevention Of Cracks In Buildings, Bureau of Indian Standards, New Delhi 6

Books

1. Building Construction , P.C Varghese, PHI Learning Pvt. Ltd., Delhi – 092
2. Limit State Design Of Reinforced Concrete ,P. C. Varghese PHI Learning Pvt. Ltd., Delhi – 092
3. Foundation Engineering, P.C Varghese, PHI Learning Pvt. Ltd., Delhi – 092
4. Structural Design of Multi-Storeyed Buildings,Varyani U.H. South Asian Publishers, New Delhi
5. Condition Assessment of Concrete in the RC Structural Elements by M/s Hi-tech Concrete Solutions, Chennai Private Limited, for M/s Greater Chennai Corporation (GCC)
6. Construction of 960 tenements adopting Prefab Technology at Murthinagar Road, Vysarpadi, Chennai.by TAMIL NADU SLUM CLEARANCE BOARD
7. Good Practice in Construction, Er. M. Kumar Chief Engineer TNPHC Ltd

WE SHAPE OUR BUILDINGS THEREAFTER THEY SHAPE US



TECHNICAL HAND BOOK ON BUILDING CONSTRUCTION FOR FIELD ENGINEERS

2018