International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 04 Issue: 05 | May -2017 www.irjet.net p-ISSN: 2395-0072

STRUCTURAL AUDIT OF RCC BUILDING

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Abstract- *Structural audit is the technical survey of the building in order to check its strength and stability. Structural audit is the first step in repairing procedure of the building. Structural audit is generally recommended for older buildings. Structural audit was first introduced by Indian society of structural engineers. structural audit helps in improving the safety, efficiency and gives idea about the strength of the structure by detailed technical inspection. In present study attempt have been made to carry out structural audit of the old RCC building by carrying out site inspection, performing NDT on the structure. Building is modeled and analyzed using ETABS and Demand to capacity ratio is determined. After checking strength and stability of the structural members suitable recommendations are given in order to retrofit unsafe structural component. Finally structural audit report is prepared for the building.*

Key words: Structural audit, NON-Destructive testing, ETABS Modelling, Structural plan, Demand to capacity ratio, Repair and retrofit.

1. INTRODUCTION

Structural audit is the overall health and performance checkup of the building like doctor check the patient. Structural audit helps to understand the status of the old building. The Audit helps to highlight & investigate all the risk areas, critical areas and whether the building. needs immediate attention. It cover the structural analysis of the existing frame and highlight the weak structural areas for static, wind & earthquake loads. If the bldg. has changed the user, from residential to commercial or industrial, this should bring out the impact of such a change

1.1 Need for Structural Audit

Structural audit is carried out in order to

- To increase life of property
- To know the health of building and its expected life.
- To check actual reliability of the structure.
- In order to recommend rehabilitation techniques.
- In order to highlight the critical areas and repair them immediately.
- For structural audit certificate required by municipality and other authorities.

Structural audit involves through examination of the building which involves:

Noting all visible defects , highlighting critical area of defects. Diagnosis of damage. Carrying out necessary NDT, Suggesting remedial measures.

1.2 Object of project

- Performing preliminary inspection of the building.
- Preparation of architectural, structural plan of the building.
- Visual inspection to highlight critical area.
- Performance of NDT tests.
- ETABS modeling of the building.
- Finding actual strength of the building.
- Suggesting remedial measures

2. METHODOLOGY

2.1 Introduction:

In order to carry out structural audit old RCC building is selected of age around 50 years.

Steps involved in structural audit carried out is as follows:

Step 1: Preparation of architectural and structural plan of the building. Architectural and structural plans are helpful in structural calculation, identifying or highlighting critical areas in the building;

Step 2: Making assumption of load based on the intended use of the building i.e whether it is commercial, residential . Finding which code requirement has been met.

Step 3: Preliminary inspection of the building:

This inspection involves 1. Visual inspection

2.Tapping observation.

1. Visual inspection

In this building is thoroughly inspected from flat to flat noting cracks, spells, crazing, seepage ect. Highlighting critical area of investigation and repair same is marked on the plan of the building.

2. Tapping observation.

During this observation some of the structural members area subjected to hammer tapping and tapping sound is noted i.e whether it is hollow or dence.

Step 4:Test recommendation

After highlighting critical area in the building next step is to recommend the appropriate test to evaluate the structure which may include Non-destructive tests like

1.PROFOMETER TEST

2.REBOUND HAMMER TEST

3.ULTRASONIC-PULSE VELOCITY TEST

4.HALF CELL POTENTIAL METER TEST

5.CHEMICAL TESTS: A.CHLORIDE CONTENT

B.SULPHATE CONTENT

C.PH VALUE

Step 5: ETABS modeling

This step involves preparation of ETABS model of the building order to find response of the structure to gravity and earth quake loading. This step will give demand of the building to the loading.

Step 6: Finding actual capacity of the members and finding Demand to capacity ratio for structural members.

Step 7: Recommendation of remedial or retrofitting methods for the suitable structural Members.

Step 8: Preparation of structural audit report.

3. PRELIMINARY INSPECTION AND BUILDING DETAILS

Year of construction-1968

Age- 49 years

Effects of monsoon - Yes

Fig 3.1: Junta Quaters

NAME: JUNTA QUARTERS

- **LOCATION: GOA,MAPUSA**
- **STOREY: G+2**
- **TYPE:RESIDENTIAL**
- **STOREY HEIGHT:3.4m**
- **EARTHQUAKE ZONE:3**
- **NO OF FLATS: FOUR 2BHK FLATS ON EACH FLOOR**

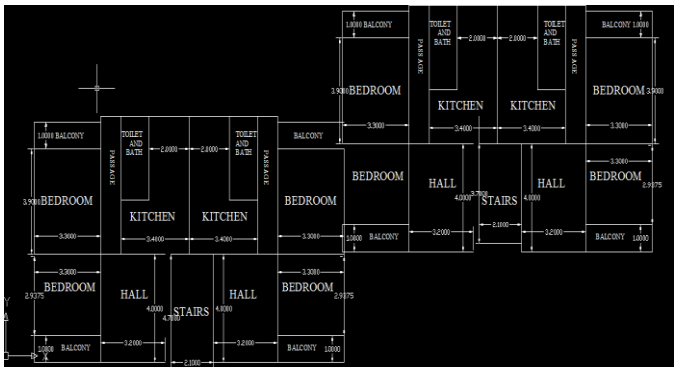

Fig 3.2: Architectural plan

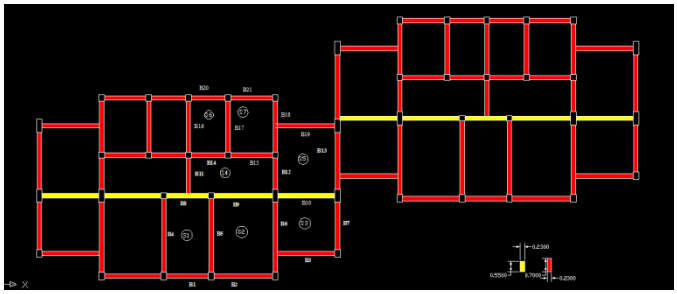

Fig 3.3: Beam layout

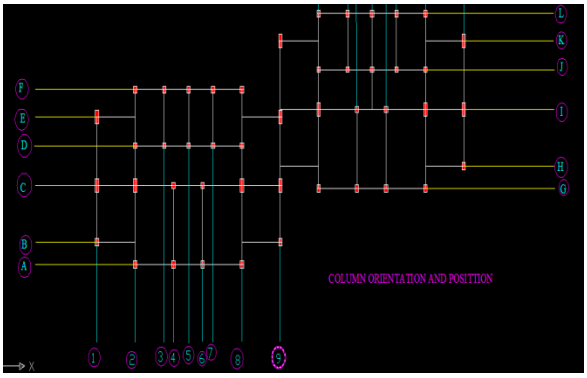

Fig 3.4: Column orientation

4. RAPID VISUAL INSPECTION AND TAPPING OBSERVATION

1. Visual inspection: In this building is thoroughly inspected from flat to flat noting cracks, spells, crazing, seepage ect. Highlighting critical area of investigation and repair same is marked on the plan of the building.

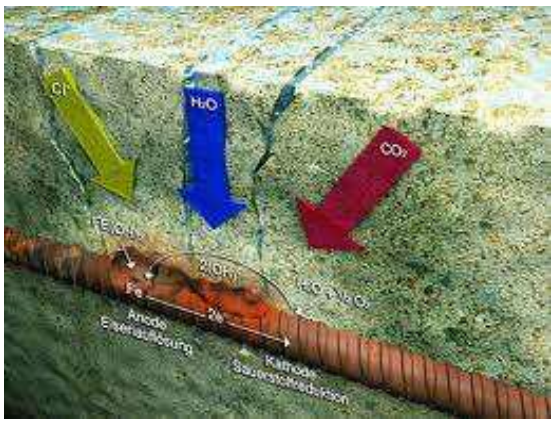

Fig 4.1: Cracks in structural members due to corrosion

2.Tapping observation: Column and beams of the building were subjected to tapping by the hammer .For some of the beams and column hollow sound was recorded. This hollow sound was due to loss of integrity between reinforced steel and surrounding concrete.

Selection of critical area for further Non-Destructive testing: Based on above observations flat no:2 of the ground floor was found most unsafe due to bad condition of structural elements such as beam, column and slab. Status of beams of this area is critical beams are sagging due to deflection and corrosion. There is bulging in column due to corrosion of reinforcement and dis-integration of concrete has resulted in exposure of the reinforcement.

5. NON DESTRUCTIVE TESTIING

Non-destructive Testing method are the method of testings in which properties of material or condition of the material is determined without damaging or making changes in the object. This methods of testing allows to test the material or component without losing its usefulness.NDT method helps in testing integrity of concrete or structural members throughout its life span.

Once the NDT tests is performed it is possible to re-test the structure or the object.

NDT tests are applicable in testing the condition of the bridges, highways, building ect. NDT allows users to determine following properties of the object

- Strength properties at site
- Durability
- Density

- Moisture content
- Elastic properties
- Extent of visible cracks

5.1 Classification of NDT Techniques.

1: Non Destructive Tests for Concrete

- Rebound Hammer Test
- Ultrasonic Pulse Velocity Test

2: Partially Destructive Tests for Concrete

- Penetration Resistance Test (Windsor Probe)
- Pull-out Test
- Pull-off Test
- Break-off Test
- Core Cutting

3: Test for Hardened Concrete

- Chemical Tests
- Test for Determination Sulphate
- Test for Determination Chloride
- Test for Alkalinity
- Carbonation Test
- Tests for Absorption & Permeability

4: location of Reinforcement, size and corrosion

- Rebar Locator & bar sizer
- Corrosion mapping
  - Half-cell Potentiometer
  - Resistivity meter

5.2 Tests recommended for Structural audit of the building

1. **Rebound Hammer**: For determination of the compressive strength of the concrete
2. **Profometer test**: Location of rebar and cover

5.3 Rebound Hammer

Application of rebound hammer test:

1. : For determination of the compressive strength of the concrete
2. Determine uniformity of the concrete.
3. Determine quality of the concrete.

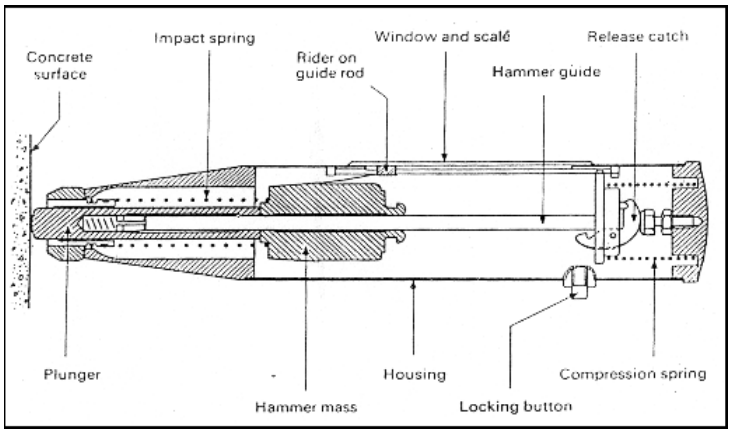

Fig 5.1: Components of Rebound hammer test**:**

Method of testing:

1. Prepare the instrument for the test,remove the plunger from lock position by pushing the plunger on the surface and push it slowly against the surface.
2. Hold the plunger perpendicular to the testing surface.
3. As the body is pushed, the main spring connecting the hammer mass to the body is stretched. When the body is pushed to the limit, the latch is automatically released and the energy stored in the spring propels the hammer mass towards the plunger tip. The mass impacts the shoulder of the plunger rod and rebounds.
4. This rebound distance is measured on the graduated scale and is termed as rebound number.

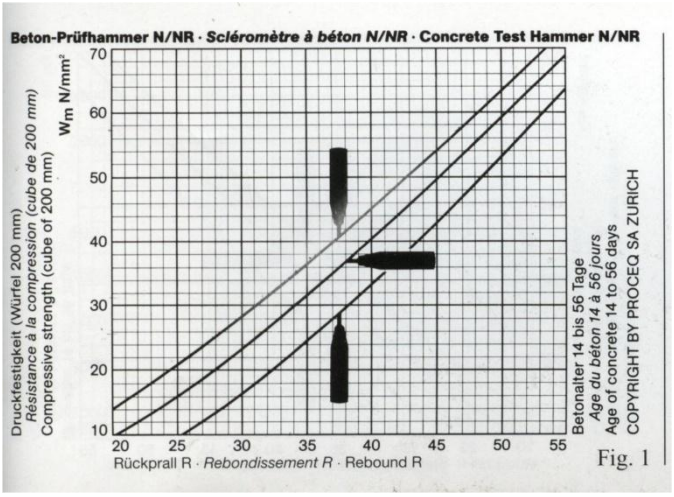

Fig 5.2: Rebound hammer chart

5.4 Results of rebound hammer number:

SL NO	SLAB LABEL	HAMMER POSITION	REBOUND NO	COMP STRENGTH
1	S1	VERTICALLY UP	29	16
2	S2	VERTICALLY DOWN	20	16
3	S3	VERTICALLY DOWN	22	16
4	S4	VERTICALLY DOWN	26	17
5	S5	VERTICALLY DOWN	24	18
6	S6	VERTICALLY DOWN	20	16
7	S7	VERTICALLY DOWN	26	17

Table 5.1: Rebound hammer number for slab

Compressive strength for column:

SL NO	COLUMN NO	COLUMN SIZE	POSITION	REBOUND NO	AVG	HAMMER POSITION	C.S
1	A6	300X400 MM	BOTTOM	10	10.67	HORIZONTAL	<10
			MID	12		HORIZONTAL	
			TOP	10		HORIZONTAL	
2	A8	300X400 MM	BOTTOM	32	29.00	HORIZONTAL	24
			MID	31		HORIZONTAL	
			TOP	24		HORIZONTAL	
3	B9	300X400 MM	BOTTOM	34	31.33	HORIZONTAL	24
			MID	34		HORIZONTAL	
			TOP	26		HORIZONTAL	
4	C6	300X400 MM	BOTTOM	27	29.00	HORIZONTAL	24
			MID	30		HORIZONTAL	
			TOP	30		HORIZONTAL	

Table 5.2: Rebound hammer number for Beam

Rebound hammer number for beam:

SL NO	BEAM NO	BEAM SIZE	POSITION	REBOUND NO	AVG	HAMMER POSI	C.S
1	B1	230X700	START	30	30.67	VERTICALLY UP	15
			MID	30		VERTICALLY UP	
			END	32		VERTICALLY UP	
2	B2	230X700	START	32	21.33	VERTICALLY UP	10
			MID	20		VERTICALLY UP	
			END	12		VERTICALLY UP	
3	B3	230X700	START	26	21.67	VERTICALLY UP	10
			MID	20		VERTICALLY UP	
			END	19		VERTICALLY UP	
4	B4	230X700	START	31	30.67	VERTICALLY UP	15
			MID	29		VERTICALLY UP	
			END	32		VERTICALLY UP	
5	B5	230X700	START	30	31.67	VERTICALLY UP	15
			MID	31		VERTICALLY UP	
			END	34		VERTICALLY UP	

Table 5.3: Rebound hammer number for column

5.4: Profometer test

Object of test:
Objective of the test is to determine
1.Size of the bar
2. Numbers of bars
3.Cover to the reinforcement
4.Aangement of the bars.

Principle of operation of profometer:
Profometer is based on the principle of magnitising the reinforcement and inducing eddy currents. After the end of the pulse eddy currents dies away and this signals are processed to get depth of measurement. Eddy current echo also determines size ,number and arrangement of the bar.
Basic principle of this method is that presence of steel affect the Electromagnet.
Profometer is avalaible in three models namely:
Model 'S',
Model 'S+',
Model 'SCANLOG'

Model used:

Model 'S'

This is standard equipment and is used for locating rebars, measuring concrete cover, storing and evaluation of data. It also displays location of rebar and concrete cover on a LCD monitor.

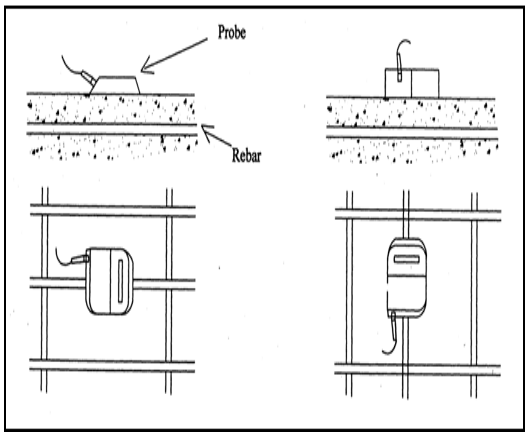

Fig 5.3: Profometer

Limitations of profometer test:

1. Cover is likely to be higher than true value When Reinforcement less than 10mm diameter, high tensile steel or deformed bars are used .
2. when special cement, including high alumna or added pigments is used Cover measured lower than the true value.

Results of profometer test

Determination of column reinforcement

SL NO	COL	COL SIZE	STEEL
1	A6	300*400	6#16
2	A8	300*400	6#16
3	B9	300*400	6#16
4	C6	300*300	4#16,2#12
5	C8	300*300	4#16,2#12
6	C9	230*700	4#20,2#16
7	D5	300*300	4#16,2#12
8	D7	300*300	4#16,2#12
9	D8	300*300	4#16,2#12
10	E9	230*700	4#20,2#16
11	F5	300*350	4#16,2#12
12	F7	300*350	4#16,2#12
13	F8	300*350	4#16,2#12

Table 5.3: Beam reinforcement

Determination of beam Reinforcement:

SL NO	BEAM NO	BEAM SIZE	Reinforcement
1	B1	230X700	2-#12
2	B2	230X700	2#12,1#10
3	B3	230X700	2#12,1#10
4	B4	230X700	2#16,2#12
5	B5	230X700	2#16,2#12

Table 5.4: Column reinforcement

6. ETABS MODELLING

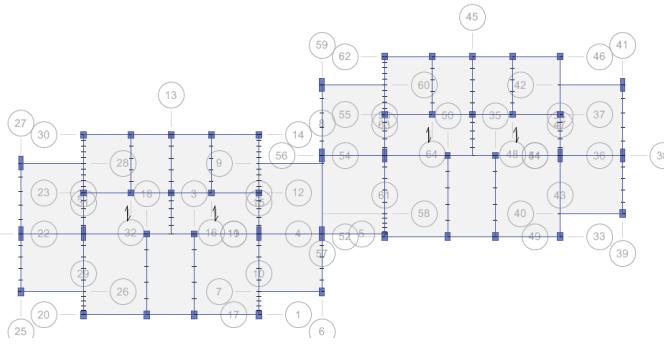

Fig 6.1: ETAB Plan:

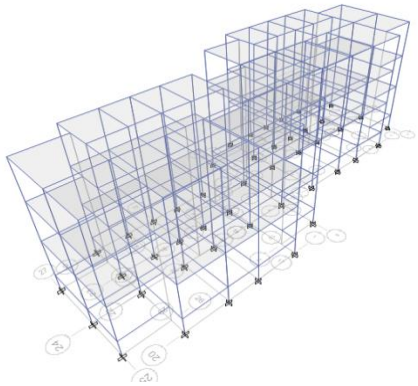

Fig 6.2: ETABS 3D Model:

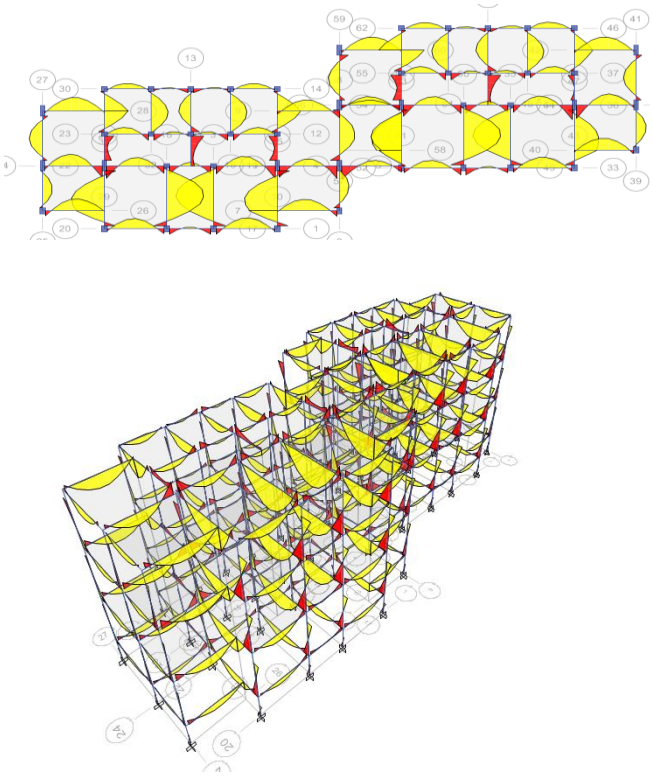

Fig 6.3: ETABS Analysis results:

SL NO	COL	PU KN
1	A6	644
2	A8	516
3	B9	370
4	C6	694
5	C8	872

ETABS RESULTS:

SL NO	Beam	MU KN-m
1	B1	19
2	B2	32
3	B3	35
4	B4	85
5	B5	85

7.DEMAND TO CAPACITY RATIO

Determination of capacity of beams

Step 1: Determine size of the structural members ,actual reinforcement present in the members.

Step 2: Determine the actual load and momemt carrying capacity of the members using IS:456:2000 . To get actual capacity of the members.

Step 3: Capacity of the structural members is determined using ETABS analysis of the members carried out in previous step.

Step 4:Compute demand and capacity ratio for the members.

Step 5: Recommend the remedial measure.

SL NO	BEAM	STEEL	CAPACITY(KN)	DEMAND(KN)	D/C RATIO
1	B1	2-#12	52	19	0.37
2	B2	2#12,1#10	69	32	0.46
3	B3	2#12,1#10	69	35	0.51
4	B4	2#16,2#12	69	85	1.23
5	B5	2#16,2#12	69	85	1.23
6	B6	2#16,1#12	69	72	1.04
7	B7	2-#12	69	21	0.30
8	B8	2#12,1#10	69	27	0.39
9	B9	2#16	69	42	0.61
10	B10	2#16	69	39	0.57

Table 7.1: Demand to capacity Ratio

8. RECOMMENDATION

From above observation of the building we conclude that:

Due to combined effects of carbonation, corrosion & effect of continuous drying and wetting and harsh weather condition building structure is in really bad condition and should be subjected to the repair immediately.
Structural building appears to be unsound due to external and internal defects. Structural members shoes cracks due to corrosion of the RCC members.
Major cracks observed accelerate the passage of water through the wall resulting in leakage of the water.
Looking at the aspect of building maintainance it is recommended to repair the building in planned manner.
In RCC framed structure ,RCC members are the major load taking elements so they cannot be left unattended for long period of time.
Original strength of the RCC members can be restored by polymer modified mortar method.

Major damage in RCC members are due to seepage of water in the members this need to be prevented by stoping the seepage of water into the members.

Seepage of water in members can be stopped by
a) Structural Repairs
b) External Plaster
c) Crack Filling/Joint Filling.
d) External Drain down take Plumbing
e) Terrace waterproofing by using non destructive method.
f) Dead wall / Internal Terrace parapet wall plaster repairs.

Rehabilitation of the RCC members

Propping the structure wherever necessary
Removing loose/disintegrated concrete
Cleaning the affected steel
Adding steel wherever necessary
Applying Passivator coat to the steel
Applying Bond Coat and doing Polymer /MicroConcrete treatment depending on the requirements
Finishing with new plaster

Rehabilitation techniques recommended:
1. Polymer Modified Mortar Treatment
2. Jacketing to columns - Microconcrete.
3. Recasting of Slabs/ Chajjas
4. Water proofing Treatment

9. CONCLUSION:

For framed structure structural audit is necessary so that appropriate remedial measures can be recommended for all types of structural defects and damages .So that it continues to serve strength and serviceability requirement.
For any structure it is necessary to carry out structural audit at least once in the five years.
For structure older than 15 years structural audit should be carried out once in 3 years.

From above observation we conclude that even though heavy reinforcement is provided for the structural members and demand to capacity ratio is less than one for all structural members . Reinforcement provided is in very bad condition and lost its Strength due to corrosion .Due to corrosion there is reduction in the cross section of the reinforcement resulting on deflection under their own weight therefore unsafe to carry any further load.

It is observed that main cause of damage of the structural members is due to corrosion and ageing. Corrosion in structural members is observed due to dampness and leakage from the slabs,cracks in walls ect.

So the strength and serviceability of the building can be increased by taking necessary measures such as: Water proofing slabs and walls to stop seepage of water into structural members so as to avoid further corrosion. Providing polymer mortar treatment.Recasting of slab ect.

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