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# Damage Detection in Beams by Advanced Radiographic Testing

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***Abstract:*** **Damage can be defined as change introduced into a system that adversely affects its current or future performance. It is a relative measure determined through comparisons between a current state of structure and an initially undamaged state. Damage in a structure can pose serious threat to its structural integrity. Thus Structural Health Monitoring, the process of identifying the damage in a structure and its adverse effects and suggesting a suitable remedy becomes important. This study aims at developing an automatic method for the damage detection in the structures and its analysis. Detection of damages is carried out using image processing techniques and these damages are analyzed using commercial FEA software. Digital image processing involves using computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing have many favours over digital image processing. It takes a much range of algorithms to be applied to the input data and it can avoid problems such as noise and signal distortion during processing. Since the images defined over two dimensions analog image processing may be modelled in the form of structural systems.**

**In the present work, cubes and cylinders are casted, tested and are modeled and CT scanner. Two types of beams were casted. One was a normal healthy plain concrete beam and the other one was a damaged beam in which damage was induced in the form of shear notch crack. These are modeled and analyzed using finite element software ANSYS, which has the required pre- and post- processing options to capture the stresses and displacements developed in the beam.**

***Keywords:*** **CT Scan, Concrete Structures, X-ray, and ANSYS.**

## I. INTRODUCTION

Maintaining concrete structural systems has become an enormous concern for the development Engineers. Structural observation is being employed to assess the practicality and safety of concrete structures. Visual examination of the structures provides obscure plan except for real time it needs a lot of attention towards degree of impact. Advanced tools are significantly needed to assess the harm an additionally verify its accountable factors. There a varied techniques that will be utilized in the tomographic imaging of structural systems. X-ray was picturing and CT scan imaging are of the vital techniques as functions of resolution and prices. X-ray picturing lets the gathering of high-resolution pictures in tiny specimens which will be far from the structure. as a result of the value and issues of safety x-rays aren't utilized in the sector. Whereas supersonic testing could also be used get stiffness pictures with lower resolution as a result of issues of high attenuation, optical phenomenon and scattering around aggregates and inclusions. but the value of supersonic testing is way not up to X-ray imaging systems. This paper presents experimental results of X-ray and supersonic tomographic imaging of concrete beams, blocks, cylindrical specimens ready with M20 concrete. X-ray picturing could also be used with efficiency for the gathering of advanced model parameters. the event of high resolution X-ray computerized axial tomography (CT) has incontestable sizable promise to with efficiency capture and characterize the concrete structure. X-ray CT may be a non-destructive advanced imaging technique that generates two- and three-dimensional high resolution pictures with the potential of capturing the main points of the microstructure. many studies have incontestable the potential application of X-ray CT technology to characterize completely different properties of concrete mixture. Recently, it's wont to effectively quantify air void distribution, combination orientation, segregation and surface texture. Digital Image process (DIP) techniques embrace image distinction sweetening, image noise removal, thresholding, edge detection and image segmentation.

### A) TYPES OF CRACKS:

Cracks may be divided in two categories namely

- Structural cracks
- Non structural cracks

**I) Structural cracks:**

The reasons for structural cracks could also be improper style, overloading of the structural elements, overloading of the soil on that the building is built or several different similar factors. Structural cracks place stability of the building in danger and will become troublesome to be corrected a number of the samples of structural cracks square measure intensive cracks of columns, foundations walls, slabs, beams etc.

**II) Non- structural cracks:**

Due to the modification within the size of building elements internal forces square measure developed within the buildings that cause non-structural cracks. Different reasons for non-structural cracks could also be temperature variation, wet variation, result of gases, liquids and solids on the building elements. Once the explanations for cracks square measure known the non-structural cracks will be repaired and their reoccurrence will be prevented by taking appropriate remedial measures.

### B) NON DESTRICTIVE TESTING:

In distinction to controlled laboratory conditions, unmoved examination of structures or materials poses remarkably numerous demands on NDT system. Numerous external factors that end up in the complications of examination method, at times, cannot be regulated. For instance, excessive variations in temperature may result in modifying the efficaciousness of supersonic examination or thermo graphic imaging, as most of the materials would be subjected to trivial changes in properties, comprising of wave propagation speed or emissivity. Likewise, the conditions discovered within the field would vary for the most part compared to the generally sleek surface texture discovered within the laboratory specimens. Evidently, if NDT techniques square measure applicable just for laboratory conditions, it's of restricted usage in structural health observance. Therefore, associate degree economical examination technique ought to represent a large varies of user modifications with a read to acclimate to the variable conditions. Visual examination is one among the foremost vital unmoved examination techniques. Visual examination is a base for all the opposite examination techniques. Visual discernment plays an important role, while not that the opposite NDT ways would fail to produce effective defect detection. Defects like de-lamination, wet accumulation, excessive fiber waviness or drooping will be discovered visually while not the usage of advanced ways. Occasionally human perception would be rendered ineffective for tracing defects that occur on the submerged locations. Therefore, examination needs the appliance of extra instrumentality that bridges the gap between human perception and mod technology. However, visual examination is one among the foremost vital NDT tools and can't be unpretentious. Visual examination ought to be the exam before the execution of different unmoved examination techniques.

### C) SCANNING:

These reasonably approaches square measure auspicious and might modification the approach we tend to procure style parameters in geotechnical and structural engineering. Although, every of those approaches have solely a restricted vary of application. Hence, it's crucial to characterize their potency not simply in terms of technological aspects however additionally in economical aspects for his or her implementation in engineering analysis and apply. This paper elaborates the two tomographic imaging ways: X-ray and computerized axial tomography methods in concrete specimens. The behaviour of the imaging systems are assessed with the inclusions of either rarity and low speed or high density and high speed during this experimental study.

## II. OBJECTIVES

The objectives of the study are:

- To detect the damage in the concrete beam.
- Determination that damage is present in the structure;

- Determination of the geometric location of the damage;
- To know the intensity of the damage.
- To know the response of the structure possessing damage.
- Quantification of the severity of the damage

## III. RADIOGRAPHIC TESTING

Radiographic testing (RT) dates back to the invention of x- and γ-rays within the late nineteenth century that has junction rectifier to tremendous advances within the field of scrutiny also as scientific testing. In general, picture taking imaging involves 3 elements, together with a radiation emitting supply, the specimen to be examined, and a recording device like an appropriate film or digitizing system. Whereas picture taking films square measure usually coated with associate emulsion that's with chemicals modified through ionization as radiation interacts with it, digital recording devices represent a lot of convenient suggests that of picture taking detection. In theoretical terms, picture taking energy may be a kind of radiation of extraordinarily short wavelengths, wherever higher energy levels correspond to shorter wavelengths. The necessary characteristic of radiation lies within the ability to penetrate most opaque materials whereas holding a high share of its energy to supply a picture on the alternative aspect of the check specimen. within the past, 3 main styles of radiation are applied to non-destructive testing particularly x-rays, γ-rays and neutrons. X-rays square measure made during a electronic device wherever high-speed electrons square measure centered at a target material, sometimes manufactured from metallic element, and made to move with it. Such interaction ends up in the discharge of quantum energy, or photons, that square measure capable of penetrating solid matter. This ability to penetrate matter is said to the extraordinarily short wavelength of radiation of x-rays, that is within the vary from 10-6 to 10-10 cm. The applied voltage, usually expressed in kilovolts (kV) is that the main governing issue for energy of the radiation. Most commercially applied units operate within the vary of one hundred to four hundred kV. For review functions, a rise of radiation energy can cause shorter wavelengths and a rise in material penetration. not like x-rays, γ-rays square measure emitted by unstable hot isotopes, that possess a supposed half-life. Whereas the energy of individual isotopes, like Cs, metallic element or metal, is exclusive to every material and remains a continuing, intensity can decay with time. Since exposure may be a perform of intensity and time, the extent needed for adequate penetration of a cloth won't be realizable once a precise fundamental quantity has passed. Thus, the atom should be discarded and changed for a brand new supply.

### A) COMPUTER TOMOGRAPHY:

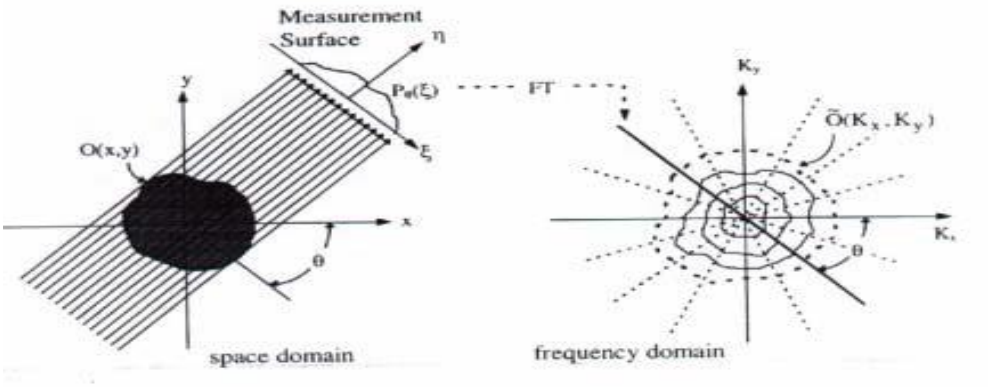


**Fig -1: Basic parallel beam computerized tomographic image reconstruction.**

Computer picturing (CT), conjointly referred to as processed radioactive picturing, is there construction of a cross-sectional image of associate degree object from its projections. In alternative words, it is a coherent superposition of projections obtained employing a scanner to reconstruct a picturing of the thing. Mathematical formulation of CT was performed by atomic number 86 in1917, and was 1st utilized in drugs as a diagnostic tool when the invention of the X ray computed tomographic scanner by Hounsfield in 1972.

## IV. CASTING

The concrete specimen of beams, cubes and cylinders are casted. The mix ratio is taken as 1:1.5:3 and w/c ratio of 0.45.

**Table -1: Concrete specimens casted**

| Specimens | Dimensions | No | 1st crack | Final load |
|---|---|---|---|---|
| Cubes | 150x150x150 | 3 | 34.5kn | 86kn |
| Cylinders | 100mmØ;h=200mm | 3 | 6.8kn | 7.5kn |

**Fig -2: Casting under progress.**

Notches resembling flexure cracks are introduced into the beams.

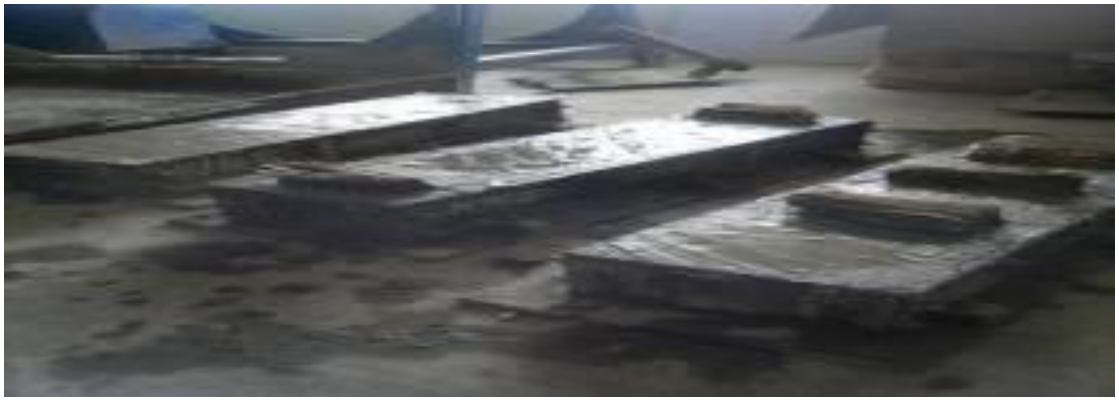

**Fig -3: Notches introduced in Beams.**

The specimens are then kept for curing in water tank for 28 days and then removed.

**Fig -4: Specimens after 28 days of curing.**

**A) Case I– Cubes and Cylinders:**

**1 Testing of specimen:**

All the specimen is kept for testing, crack generation and propagation of crack is observed. The tested specimens are preserved to study further the effect of cracks on the structure. Cubes are tested for compression & Split tensile test is done on cylinders.

**Fig -5: Compression Test**

**2 Test Results:**

Cubes and concrete showed proper development and propagation of cracks throughout the length and width of the specimen.

**Fig -6: Crack developed along the Cross Section**

**Fig -7: Crack along the length of cylinder.**

**Fig -8: Crack propagating in cube.**

### 3) CT Scanned Images of the Specimen:

The specimen of concrete are CT Scanned to obtain more detailed information of a number of slices of all concrete samples both Healthy and Cracked are obtained. Some of which are as shown below.

Once the crack propagation is seen in the concrete the same can be accurately obtained in CT scan image, thereafter to know the further structural response and stress in the structural element, the same was modelled using finite element software ANSYS.

**Fig -9: specimen kept for CT scanning**

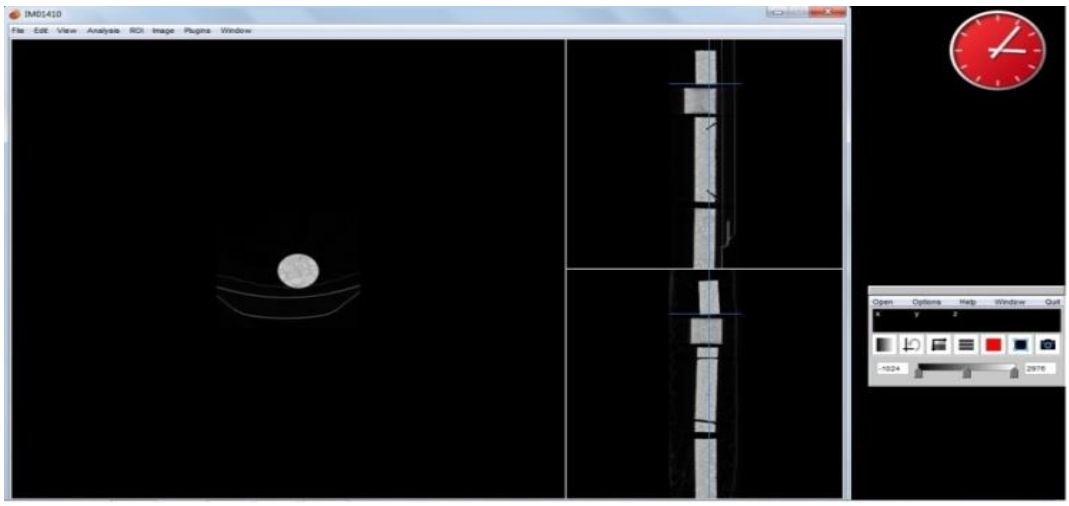

**Fig -10: CT scan image**

**4) Scanned images of the entire specimen;**

Figure 4.8 shows the series of specimen queued in the CT scanning machine. The scanning of specimen is done at every 2mm distance for the entire specimen who clearly gives the insight view of the entire specimen and the orientation of mortar and jelly can be clearly seen.

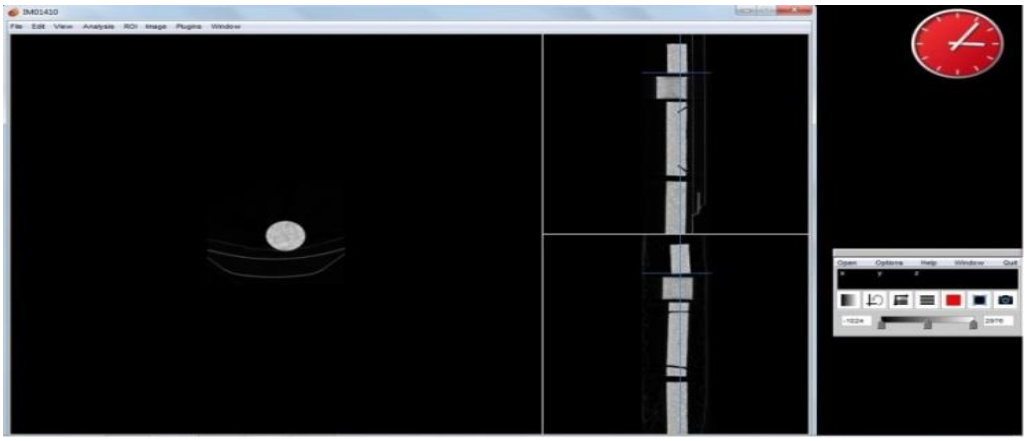

**Fig -11: CT scan image**

The CT scanner uses digital geometry processing to generatea3-dimensional (3-D) image of the inside of an object. The 3-D image is made after many 2-dimensional(2-D) X-ray images are taken around a single axis of rotation-in other words, many pictures of the same are a are taken from many angles and then placed together to produce a 3-D image. The Greek word "tomos" means "slice", and the Greek word graph in means "write".

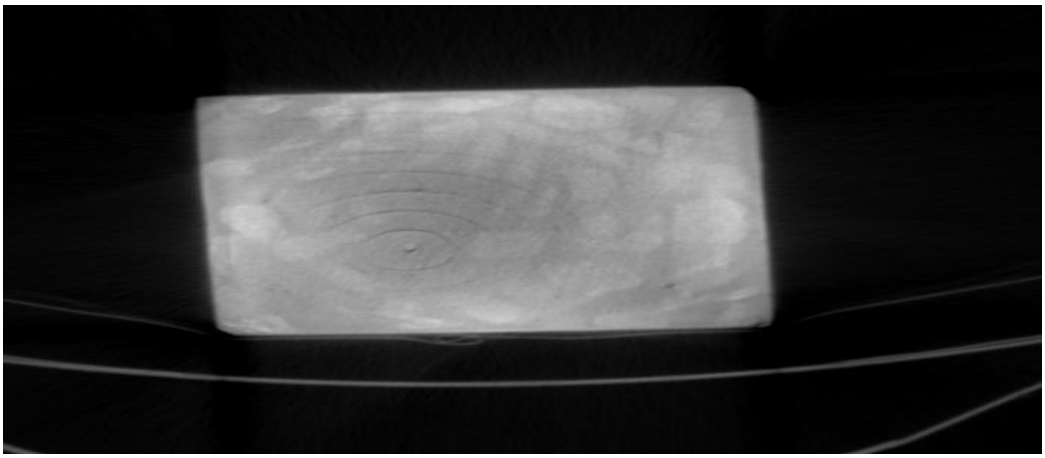

**Fig -12: CT scan image of a healthy cube.**

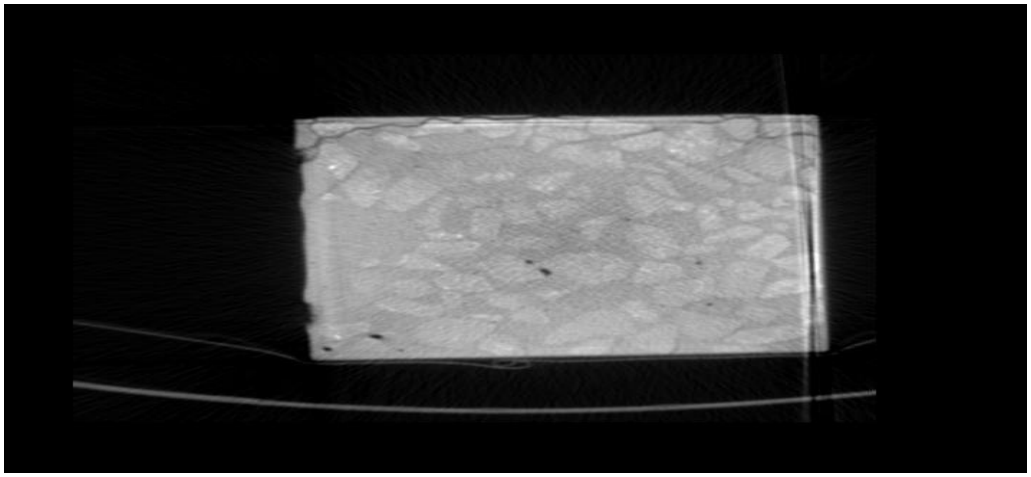

**Fig -13: CT scan image of a cracked cube**

Figure-13 shows one of the slices of the concrete cube sized150×150x150mm, the cube is healthy and is not tested for compression and the figure4.13shows the CT scanning image of the cube tested under compression and propagation of crack is very clear and we get to know the insight view of the crack in the specimen.

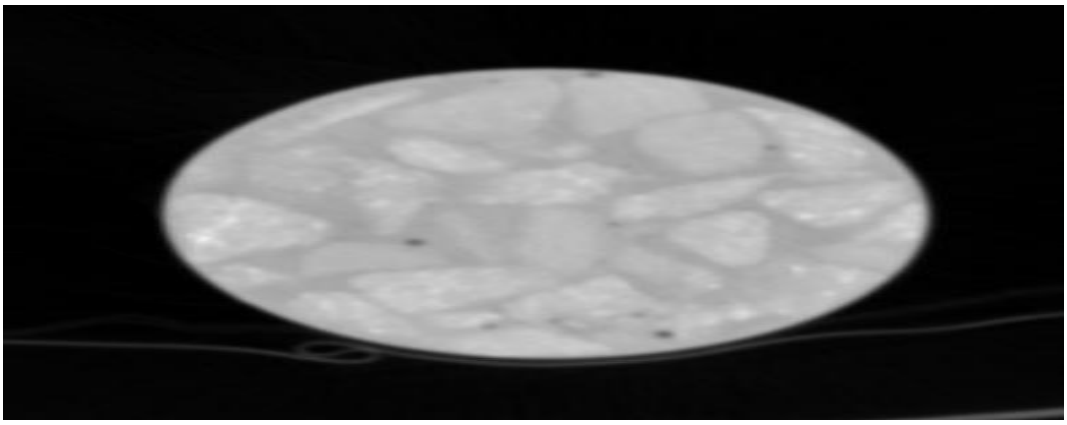

**Fig -14: CT scan image of a healthy Cylinder**

Figure-14 shows the CT scan image of a healthy cylinder black dots represent the air voids and after the split tensile test the tensile crack developed along the cross-section of the cylindrical specimen is seen clearly in figure-14.The images are obtained at every 2mm slice of the specimen hence proving to be of great importance for knowing the crack propagation inside and is helpful in judging the health of the structure.

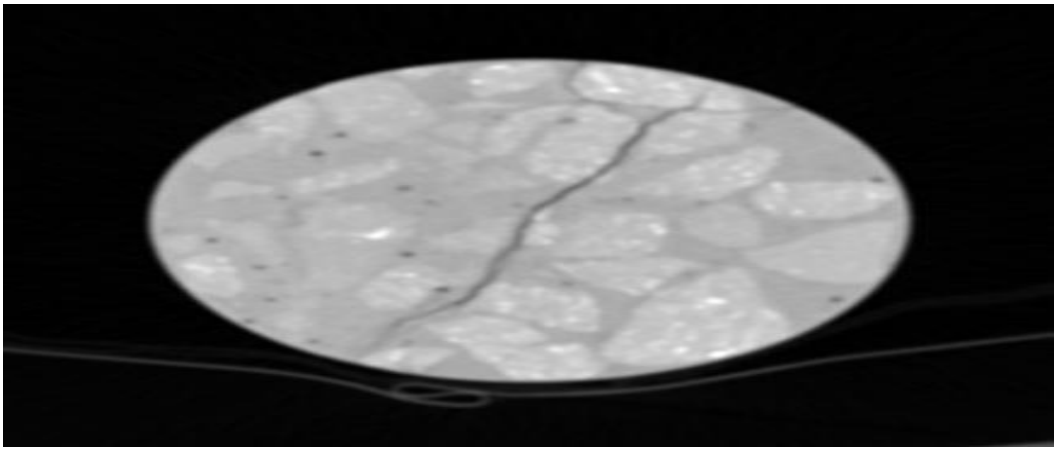

**Fig -15: CT scan image of a cracked cylinder**

## V. CONCLUSIONS

- Presence and extent of the damage in the structure can be known.
- Repair strategies and need for retrofitting can be judged. The condition and future use of the structure can be predicted.
- The approach is found to be very useful in depicting the actual crack width and its propagation within the structure, thus giving us a clear perspective of the interior of any structure.
- The computer model made using this data will hence be giving more effective stress results. Therefore the approach is of great help in decision making for the rehabilitation and retrofitting of structures.
- Using the projected technique the structural failure will be foreseen abundant before its actual prevalence because the information obtained from the CT scan pictures will be processed in any finite element software and therefore the stresses iatrogenic will be clearly monitored. Repair ways and wish for retrofitting will be judged.
- Once the cracks iatrogenic within the structure is thought and stresses generating within the structure is obtained

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