計畫編號：BE03-01
計畫名稱：異質性流體與固體系統之微力學理論與大型計算研究
計畫主持人：楊德良
計畫摘要(中)：

本子計劃主要工作內容在於建立一創新的流體與固體互制模式，以深入探討土石流發生的機制行為。期有效分析土石運動此複雜的物理系統，本計畫將由巨觀的理論建立及微觀的力學數值分析兩個方向個別探討。在數值模式的部份，我們將直接模擬不可壓縮那維爾史托克斯流與粒子之間的複雜流固互制行為，為了有效處理此複雜系統衍生的龐大矩陣計算，有效率的平行計算程式與可靠的大型平行計算平台的設立將會是此部分的工作重點。至於理論建構方面，則著重於流固運動及互制行為的整體行為，主要分為粒子流、泥流以及土石混合流三部份，並於計畫中個別做探討。

計畫摘要(英)：

The proposed sub-project aims to develop a novel modeling technique to characterize the dynamic behavior of the heterogeneous fluid-solid system as the occurring mechanism of the debris surges. Due to the complicated system, our research tends to investigate the debris flow surges from two different points of view. One regards the debris flow as the incompressible Navier-Stokes flow involving heterogeneous solid-fluid mixtures. A large-scale computational model is developed to study the micromechanics interaction between the constituents of debris flow surges, and structural responses to the flow. The other is to theoretically study the dynamics of debris flow in three phases, in each one of which we have independent subjects mainly related to the dynamics of stone flow, mud flow, and the mixture of stone and mud, respectively.

計畫編號：BE03-02
計畫名稱：固液二相流於微觀力學行為下的內部影像實驗分析與理論建立
計畫主持人：卡艾瑋
計畫摘要(中)：

本子計畫將會利用新穎的實驗技術及經過適當簡化過的理論來

探究在高濃度土石流和渾濁流中的固體與液體之互動。計畫之目標係藉由微觀的角度去更近一步了解此種流體 (泥流或濁流、沙礫、岩石碎屑和包含樹木之土石流) 與浸泡在此種流體中之結構物 (橋墩、停機坪和基腳) 的相互運動。實驗的第一個部份係利用特殊的履帶機設備製造出包含數以萬計之顆粒所構成之穩定土石流。實驗的第二個部份會把重心放在利用少量顆粒來測試顆粒與顆粒、顆粒與液體及流體與結構之相互運動。最後，實驗的第三個部份將會檢視由重力驅動或射流導之粗顆粒渾濁流之運動。以上所有之實驗，我們將利用最新研發之影像技術來量測流體與固體之相互運動。透過相同折射率之固體與液體、醫學用內視探針或聲納影像量測技術，我們將可以擷取到高濃度流內部之動力資料。擷取出來之資料將透過影像處理技術來獲得速度場及濃度場。最終，透過適當簡化的理論 (慣性流體動力學及多物體運動之統計分析) 可對結果做進一步的闡述。

計畫摘要(英)：

This sub-project will use novel experimental means and simplified theory to characterize solid and liquid behaviors in high-concentration debris and sediment-laden flows. The aim is to better understand micro-mechanical interactions between the heterogeneous constituents of such flows (muddy or turbid liquid, sand grains, rocks, and woody debris), and between these constituents and structural elements immersed in the flow (bridge piles, aprons, and foundations). The first set of experiments will include debris flows involving thousands of particles, made stationary in the laboratory frame of reference using a special conveyor belt apparatus. A second set of experiments include simpler tests featuring smaller numbers of particles and focused on specific aspects of particle-particle, particle-liquid, and flow-structure interactions. Finally, a third set of experiments will examine gravity-driven or jet-induced turbidity currents driving the motions of coarser grains. For all experiments, internal imaging of the fluid and/or solid motions will be sought using newly developed techniques. Access to the internal dynamics of the highly-concentrated flows will be sought using refractive index matching, boroscopic probes, or sonar imaging. Image processing methods will then be used to obtain measurements of velocities and concentration inside the bulk. Finally, interpretation of the results in terms of simplified theory (inertial flow dynamics and statistical analysis of multi-body motions) will be sought.

計畫編號：BE03-03
計畫名稱：橋梁沖刷之流體動力與紊流變化機制實驗研究
計畫主持人：張國鎮
計畫摘要(中)：

基礎沖刷已成為跨河橋梁所面臨的主要災害問題之一，並危及國人生命財產，然而，由於橋梁現地颱洪期間的洪水水文、水理條件極為複雜，使得監測儀器設備應用環境嚴酷，橋梁沖刷過程的流體動力與紊流變化機制研究，以及創新的現地即時監測系統研發就顯得非常重要，以便即時回饋現地結構於颱洪沖刷之安全；研究團隊所研發之光纖監測系統已於現地橋梁驗證其颱洪期間監測之可行性，本計畫將藉由微機電感測器之研發並整合無線感測網路技術，經由實驗室與現地橋梁即時的量測監測資料，深入探討沖刷過程的流體動力與紊流變化機制。無線感測網路的技術已應用於許多領域，本子計畫將透過陣列式壓力感測元件配置，結合無線感測技術來建構沖刷機制量測系統，並整合加速度、溫度、濕度、角度等感測器研發現地即時橋梁沖刷監測系統。此無線監測系統的研發除可用於研究基礎沖刷與橋梁安全機制之外，並可針對河床土壤於沖刷歷程的變化進行量測研究，為突破既有傳統之創新技術。

計畫摘要(英)：

It is well known that scour is one of the major causes for bridge failure. Scour failure tends to occur suddenly and without prior warning or sign of distress to the structures. However, the challenges in understanding the processes controlling hydraulic scour and developing a reliable predictive capability such as measuring equipments are essentially crucial, especially during the floods. In the previous research achievement, the application of fiber Bragg grating (FBG) to monitor the bridge scouring process had obtained the first real time in-field records in the world for a bridge scouring. A comprehensive understanding of the scour mechanics remains elusive because of the complex nature of the process. The coupling between the shape of the eroded bed profile and the hydrodynamics characteristics of the down flow as well as the vortex systems increases the complexity. Most previous studies have been experimental in nature and any attempts to theoretically model the scouring process have been semi-empirical at best. On the other hand, the detailed mechanisms of the scour processes around the bridge pier still need to be explored, typically relating to hydraulic pressures and turbulence fluctuations. The wireless micro-electro-mechanical systems (MEMS) sensor network is widely used in many fields. A novel arrayed MEMS pressure sensor for scour mechanics measurement will be development in this proposal. MEMS sensors such as pressure sensor, accelerometer, temperature, humidity, rain gauge and tilt sensor will be integrated with the ZigBee sensor network on a sensor board for real-time local bridge scour depth monitoring during a flood. This wireless MEMS scour-monitoring system will be developed and tested to characterize interactions between the heterogeneous constituents of sediment/soil, and between these constituents and bridge pier/abutment in the laboratory and in the field.

計畫編號：BE03-04

計畫名稱：雙固體顆粒固液二相流的宏觀動態行為實驗及理論模型推導

計畫主持人：楊馥菱

計畫摘要(中)：

固體液體二相混合體常見於現今的工業製程及大自然環境中：從石油產業的鑽井疏通、水泥或食品藥物之製作運送及封裝，到晶圓磨潤、精密加工或LED的填充及鍍膜；由山崩、土石流、河川淤積，到魚群運動及血管血球運動相關的醫學工程。固液介面上不可忽略的交互作用，改變混合體的本固關係式，造成二相混合體有別於單相連續體的運動行為。因此，僅管重要，現今對此種異相介質混合體的運動仍只有片面的了解。為達更有效率的系統設計、更精準的二相流控制，或對自然災害作主動性的預測及防治、突破生醫科技技術，我們對相關固液混合體的物理力學特性，實應有所掌握，其受外力作用下的動態反應，更應全面性探討。

鑒於當今研究均著重在混合體的穩態本固關係式，甚少涵蓋其動態特性，本研究將針對固液二相流的非穩態行為做系統性的探討。此外，異於實驗室裡慣用的單一固體顆粒，實際應用上的二相流混合體

通常由數種固體顆粒所組成，因此，本計劃擬藉系統的實驗觀測探討混合體的流動如何受其組成改變而影響。首重分析的參數含括：固液態密度比，顆粒尺徑比，顆粒密度或質量比。量取並歸納混合體的運動時程及堆積距離，以推算該流動狀態的特徵運動長度及時間單位，估計外界能量及動量在混合體中的傳播及損耗。此大尺度(macroscopic, flow-scale)上顯現之動態現象將與小尺度(microscopic, particle-scale)的固液體交互作用做比較，以探究二相流動態行為在顆粒及混合體兩尺度上的關聯。本計畫的最終目標，將應用實驗及尺度分析之所得，建立適用於固液二相流宏觀行為的動態模型。

計畫摘要(英)：

A solid-liquid two-phase mixture is common in many industrial processes and natural hazard problems. From gasoline drilling, slurry transportation, to surface polishing with fine particles, a solid-liquid flow can also be found in avalanches, debris flows, and river sedimentation problems. When the two heterogeneous constituents move together with comparable inertia, the frequent particle collisions and strong solid-liquid interactions make the mixture dynamics an intrinsically multi-scale problem. Thus, the resulting bulk behaviors usually deviate from that of a pure solid or liquid mass of equal potential energy. A dynamic model that feasibly represents the bulk behavior is highly desired for better, more economic and efficient, engineering design and application. This piece of information can also be used to develop an effective warning system for nature hazard and mitigation strategies.

As an attempt to answer the general big question, this research aims to investigate how a viscous and incompressible liquid constituent modifies the motion of a solid particle assembly. Unlike most of the current research that examines the constitutive relation of a solid-liquid mixture at steady flowing state, this project will focus on the unsteady bulk motion that flows down a lab-scale flume. We will estimate the characteristic time and length scales of the bulk flow through systematic experiments. The results will be examined with the well-known flow parameters—the Savage number, Sa, and the Bagnold number, Ba—that categorize the mixture dynamics by their stress distribution at steady state. New parameters that measure the unsteadiness of a solid-liquid flow will be developed. Furthermore, the obtained knowledge on bulk behavior will also be interpreted from the particle-level solid-liquid interactions. We will first estimate the particle Stokes number, St, and the particle Reynolds number, Re, which two numbers characterize different forces at particle level in a flowing mixture. In addition to the two flow parameters, Sa and Ba, the two particle-level dimensionless numbers will be employed to characterize the bulk flow. This comparison shall reveal the correlation between the microscopic solid-liquid interactions and the macroscopic mixture dynamics. The results from this sub-project shall integrate into a thorough understanding of this multi-scale two-phase flow physics. The learning will greatly assist us to develop a feasible dynamic model for a solid-liquid flow over a board flow conditions.

計畫編號：BE03-05
計畫名稱：結合外力識別,智慧型感測技術及結構健康診斷以偵測結構損壞模式
計畫主持人：羅俊雄
計畫摘要(中)：

本子計劃之主要目標在利用先進技術及發展下一代智慧型結構系统，以執行有關天然災害防治之研究。在第一階段之研究中(2006/8~2008/7)已研發出無線感測模組用以進行結構系统識別及損壞評估，同時亦進以無線感測方式進行結構控制。並於實驗場及野外完成驗証之工作。延續第一階段之研究，本研究將持續進行第二階段之研究，並將研究重點放在結構損壞狀况之預估，其中包含整合有關外力識別研究，結構健康診斷、與配合先進技術建構智慧型結構系统。此先進技術則包含着:訊號處理及分析技術、感測器之研發、智慧型感測技術、先進訊號處理結構損壞模式建立、外力模式與結構互制之識別。在此目標下本子計劃有三個主要研究方向:首先研發出由結構受外力作用下(作用力與結構互制)，配合振動量測，以識別出外力之特性。此外來之作用力包含:風力、隨機行進車輛之作用力、地震力(土壤與椿互制)、水流作用力，及土石流等。此外力識別可分別從時間域及頻率域進行研究。第二個研究重點在探討以先進訊號處理進行結構健康診斷　研發有效及可靠之無線感測技術，以進行結構健康診斷及結構損壞評估(含軟體植入無線感測系统之分散式分析技術)。第三個研究重點在開發智慧型控制器及控制理論(分散式控制及

控制錯誤忍受度)。最後結合此三個重點研究，完成結合外力識別,智慧型感測技術及結構健康診斷建立結構損壞預測模式。所有研究重點將進行室內及室外之實驗驗証。

計畫摘要(英)：

The main target of this sub-project is to conduct researches in relating to natural hazard mitigation through using advance technologies. Based on the research results from Phase I study (2006/8~2008/7), techniques on structural identification, damage detection and structural control using wireless sensing system were developed and verified through numerical simulation and experiments (both in the laboratory and in the field). Continue the research works from Phase I, the research works in Phase II will focus on the development of structural damage prognosis model by integrating input force identification, smart sensing technology, advanced signal processing and structural health monitoring methods. The advance technologies include: advanced signal processing, sensor development, damage prognosis model, and the input force identification. Under such goal three major researches will be carried out. First, develop the methodology for the identification of complex input force directly from structural vibration measurement. Both time domain and frequency domain approaches will be used to identify the external loading on the vibration structures. The input-force identification issue include: soil-pile interaction problem, debris flow on bridge pier, seismic input source, wind-structure interaction and bridge-vehicle interaction. Second, develop structural health monitoring technologies using advanced signal processing techniques. The signal processing will focus on the feature extraction from the measurements of structural response. Third, develop smart sensing systems and smart control devices. This includes upgrade the current wireless sensing unit through using the high performance microcontroller and microprocessor, wireless communication system, and embedded useful decentralized control algorithms into the microcontroller. Finally, combine these three research results to develop structural damage prognosis model which includes the development of criteria for evaluation and decision of planning, evaluation and iterative optimization of structural monitoring and the

knowledge based system (modules of the expert system) for data acquisition and assessment in monitoring structures. In this Phase-II sub-project, the outcome will be the integration of the design load and environment, and structural health monitoring techniques, so as to develop the structural damage prognosis model and to estimate the remaining service-life of structure. All the developed methodologies will be verified through laboratory experimentation and field tests.

計畫編號：BE03-06
計畫名稱：二相顆粒流計算模擬
計畫主持人：謝尚賢
計畫摘要(中)：

隨著全球氣候的變遷，由洪水引發的自然災害，例如土石流、山崩，泥流及洪災等，發生益加頻繁，且正嚴重威脅著我們的日常生活。從物理上，我們可以將這類自然流(natural flows)現象簡化為流固體之間交互作用的二相顆粒流(two-phase granular flow)。不過，其動態流動的特性-- 顆粒組成及流場隨著時間、位置產生變化，使得整體行為相當複雜。本研究藉由引入四個重要的無因次參數，即雷諾數(Reynolds number)、斯多克斯數(Stokes number)、巴格諾爾德數(Bagnold number)，及薩維基數(Savage number)，系統化地將自然流分類，以便深入了解其行為，來輔助模擬模式的開發。

本研究提出三種模擬二相顆粒流的模式，分別為離散顆粒模式、二相混合流模式，及二相流模式。離散顆粒模式主要依據離散元素法(Discrete Element Modelling)的原理，藉由適當地調整元素間碰撞時的彈性係數及阻尼係數，來反應出流體對固體顆粒的效應。因為不用計算流場，效率為三種模式中最佳，不過，也因此僅適用於流體效應較小的自然流現象。不同於離散顆粒模式，另外二種模式都必須求解流場。其中二相混合流模式是依循混合理論(mixture theory)，分別平均流體和固體的運動，然後以流固體之間的作用力將二相聯結在一起，因此如何計算交互作用力是此模式的關鍵，過去已有相當多的研究從理論、實驗，和數值等方面提出計算的方法，本研究將探討前人所提出的方法，討論不同方法所適用的自然流分類，並提出創新的交互作用力模式。二相流模式的概念則是直接求解流場，理論上，計算結果最精確，不過根據前人研究，當顆粒數增加的時候，模式的效率會大幅降低。因此，本研究將探討現有的數值計算方法，包括

Lattice-Boltzmann 及 Immersed Boundary Method 等方法，已提出創新數值計算方法，以改善現有方法之效率，且將此模式計算流固體交互作用力的結果回饋給二相混合模式，以驗證、修訂，及擴充前人的理論。

本研究的模擬結果，將會與 F. L. Yang （子計畫四）和 H. Capart（子計畫二）所主持的其他子計畫的實驗結果作驗證，並與 D. L. Young（子計畫一）的計算結果作比較，以探討各模擬模式的適用性及實用性，並推演至大尺度的自然流模擬。

計畫摘要(英)：

Flow-induced natural hazards such as debris flows, rock avalanches, mudflows, and water floods have posed a great threat to the society. Many efforts have been made to study these complex phenomena of natural flows. However, their dynamic characteristics poses a great challenge to conduct a model for capturing their motion completely. This research aims to adopt four dimensionless variables, namely Reynolds number, Stokes number, Bagnold number, and Savage number, to characterize the behavior of particles and mixtures for various natural flows.

Pertinent to the proposed classification, three types of simulation schemes will be developed herein. They are dry grains with wet spring, two-fluid model with empirical interactions, and two-phase model, respectively. The scheme of dry grains with wet spring is conceptually simple: we assume that the liquid effects can be properly lumped to the classical spring and dashpot models in discrete element modeling (DEM). Such treatment is considered to be the most efficient scheme since it does not have to estimate fluid field which usually spends most computational time and resources in two-phase problems. Nevertheless, this scheme may not be feasible for the phenomena in which fluid fields dominate. In contrast, the other two schemes stress on the technologies of estimating the fluid field. The theoretical challenge of the two-fluid model with empirical interactions scheme hinges on deriving analytically or numerically of the functional forms of empirical interaction when calculating the fluid-solid interaction. The two-phase model scheme will be developed through directly solving fluid fields. Novel methodologies and numerical technologies will be developed to speed up this scheme.

The numerical results obtained from this subproject will be compared with the laboratory experiments conducted by F. L. Yang (subproject 4) and H. Capart (subproject 2) as well as numerical results by D. L. Young (subproject 1). Finally, the proposed simulation schemes will be extended to model large scale simulation of natural flows.